REPORT

Lake Shafer Feasibility Study
Monticello, Indiana

SFLECC
P.O. Box 372
Monticello, IN 47960

Attn: Mr. Bob Coates

K&S

K&S Testing and Engineering Inc.
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March 30, 1995

File No. 2465

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P.O. Box 372
Monticello, IN 47960

Attn: Mr. Bob Coates

RE: Lake Shafer Feasibility Study
Monticello, Indiana

Dear Mr. Coates:

In accordance with our Proposal No. 1106 (dated May 7, 1993) K & S Testing and Engineering, Inc. has performed Lake Shafer Feasibility Study located near Monticello, Indiana. The report of the feasibility study is enclosed.

This report documents past, present and anticipated future rates of lake sedimentation, feasible methods to restore the lake capacity to an acceptable level, and structural and non-structural measures to minimize the rate of lake sedimentation in the future. Of the different types of sediment control methods, combination of dredging and construction of silt traps at strategic locations appears to be the most cost effective option. Requirements for periodic maintenance and the associated costs are also addressed in this report.

This investigation indicates that hydraulic dredging is most economical for Lake Shafer. An area of agricultural land identified by this report and located northwest of Lowe's bridge could be considered as an example of an area typically suitable for the disposal of dredged material. The estimated capital cost for sediment removal and disposal at an area such as this, using the recommended type of dredging, is $2,900,000.00. This estimated cost considers hydraulic dredging to cost $3 per cubic/yard and is subject to change. It is recommended that a lake survey be conducted after a period of 15 years to determine the amount of accumulated sediment needing to be dredged.

Our evaluation of the causes of lake sedimentation indicated that significant amounts of sediment are contributed by the Tippecanoe River. To minimize sediment transport attributed to the Tippecanoe River, the following actions could be considered:

> Perform a hydrologic and erosion study for the entire Tippecanoe River watershed upstream of Lake Shafer and develop a watershed management plan involving the implementation of structural and nonstructural sediment control measures.
>
> Evaluation, restoration and enhancement of the storage capacities and sediment trapping efficiencies of the lakes in the upper watershed.
>
> Conducting an additional design study for a structural measure, such as a submerged weir, upstream of the mouth of Big Monon Ditch and where the river flows into the lake.

If financing of the project in its entirety becomes difficult, then it may be advisable to undertake the construction of sediment traps and dredging operations in phases.

We appreciate the opportunity to be of service to you. If you have any questions regarding this report, or if you need additional help, please call our office.

Very truly yours,
K & S Testing and Engineering, Inc.

Dibakar Sundi, P.E.
Vice President

Petar Kostur, P.G.
President

SV:DS:PK/cag

cc: IDNR - Attn: Mr. Michael Massonne

File No. 2465

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STUDY TEAM

In order to complete Lake Shafer feasibility study, K & S utilized the services of Dr. Anand Prakash, P.E., Chief Water Resources Engineer & Associate at Dames & Moore, Rolling Meadows, Illinois as the lead consultant. However, all engineering studies were performed by K & S engineers at our Highland, Indiana office. The project team was comprised of Mr. Dibakar Sundi, P.E., Mr. Ashok Medhi, Mr. Satya N. Vasireddy, Mr. Jose Flores (Purdue University, West Lafayette, Indiana) and Miss Carrie Galik. Dr. Steve Johnson, Professor of Surveying at Purdue University, West Lafayette, Indiana provided his valuable suggestions and guidance in doing the survey. Mr. Robert E. Coates and Mr. Bill Sypher (Poncies Water Sports) were extremely helpful with many suggestions and ideas and in providing the boats and other necessities during the survey. We sincerely appreciate their efforts. We also wish to acknowledge Mr. Michael Massonne of IDNR and staff of the County Surveyor's Office at Monticello, Indiana for their help in collecting previous study reports and information.

1.0 INTRODUCTION

1.1 STUDY OVERVIEW

K & S Testing and Engineering, Inc., Highland, Indiana was awarded the contract for performing the Lake Shafer Feasibility Study at Monticello, Indiana in August, 1993.

Lake Shafer is a manmade lake which was formed by the construction of the Norway Dam at Monticello on the Tippecanoe River (Fig. 1.1). The dam was built in 1923. This lake constitutes the upper water body of a twin lakes system comprised of Lake Shafer and Lake Freeman (Fig. 1.2). Freeman Lake is located south of Lake Shafer and was formed by the construction of Oakdale Dam in 1925. A hydroelectric power plant is located at each of these dams. The dams are currently owned and maintained by the Northern Indiana Public Service Company (NIPSCO), which has operated the two (2) hydro-electric facilities since 1944. The normal yearly power output is 26 million KWH from the Norway power plant and 36 million KWH from the Oakdale power plant. Norway and Oakdale are both run-of-the-river hydroelectric projects. Except during flood events, the power plant discharges are nearly equal to the river flows entering the respective lakes. The principal waterways entering the main body of Shafer Lake are the Tippecanoe River, Big Monon Creek, Hoagland Bay, Honey Creek Bay, Keans Bay, Big Monon Ditch, Carnahan Ditch and Timmons Ditch (Fig. 1.1). The approximate storage capacity of Lake Shafer at construction in 1920 was estimated to be 14,000 acre-feet with a surface area of about 1,291 acres and a length of ten (10) miles along the Tippecanoe River.

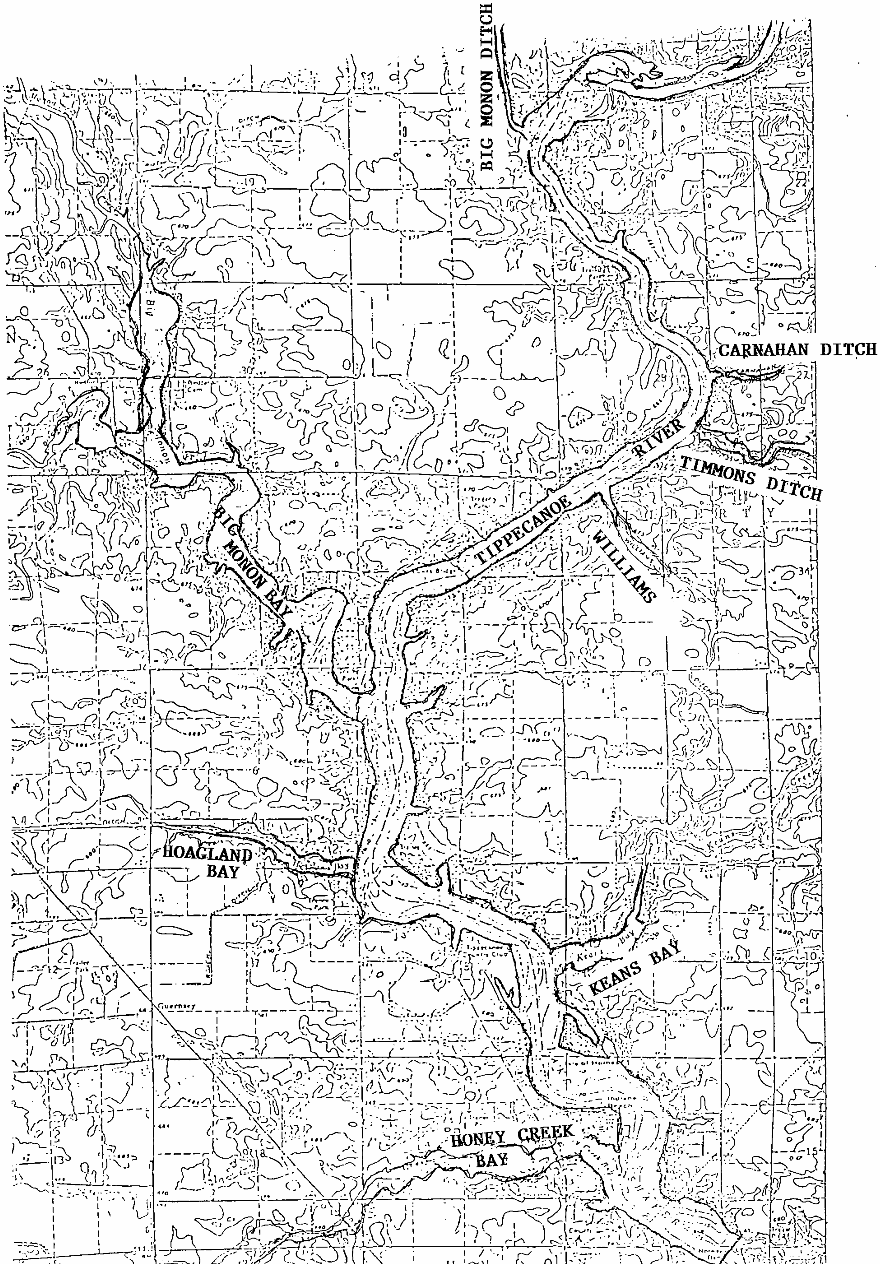

FIGURE 1.1 LAKE SHAFER AND TRIBUTARIES (MONTICELLO NORTH QUADRANGLE)

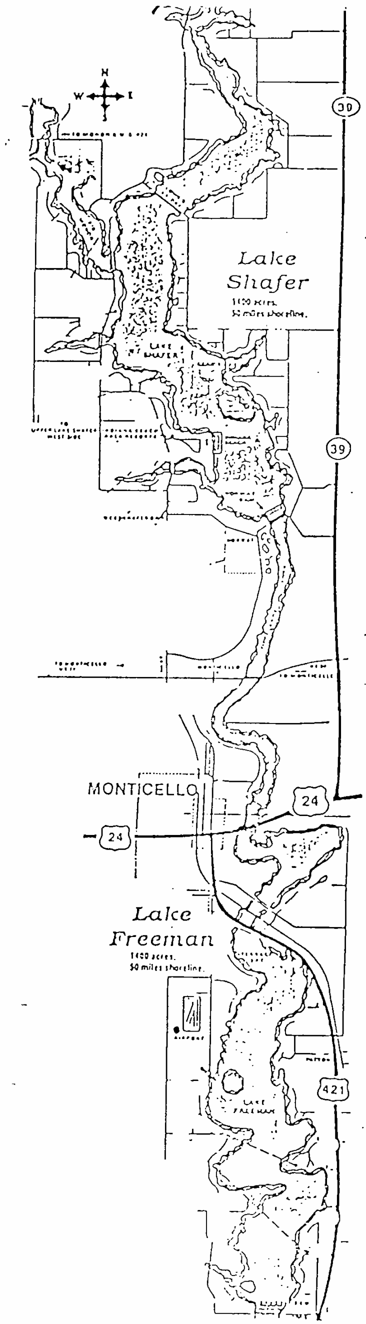

FIGURE 1.2

TWIN LAKE SYSTEM

LAKE SHAFER AND LAKE FREEMAN

Previous lake sedimentation studies have indicated a continuous decrease in the storage capacity of Lake Shafer. The present (1993) storage capacity of Lake Shafer including portions of the tributaries (bays) has been estimated to be 9,445 acre-feet. This study indicates that the rate of silting of the lake has been increasing since the construction of the dam and has been relatively high in recent years.

Lake Shafer is located near the City of Monticello in White County Indiana approximately 30 miles north of Lafayette and 60 miles south of Gary, Indiana. Numerous camps, resorts and other commercial enterprises are located around the twin lakes, Shafer and Freeman. The Indiana Beach, located approximately four (4) miles north of Monticello and one and one-half (1.5) miles north of the Norway Dam, attracts more than 700,000 people each summer offering various recreational opportunities including swimming, fishing, boating, skiing and sunbathing. In addition to streamflow diversion/impoundment for power generation, in the winter months the main uses of Lake Shafer include snowmobiling, cross country skiing and ice skating. During the past two decades, the recreational and economic value of the lake to the community has increased significantly. The apparent loss of lake capacity and constriction of waterways has become a major concern for persons using these facilities as well as local residents.

This report documents past, present and anticipated future rates of lake sedimentation, feasible methods to restore the lake capacity to an acceptable level, and structural and nonstructural measures to minimize the rate of lake sedimentation in the future. Of the different types of sediment control methods described in this report, combination of dredging and construction of silt traps at strategic locations appears to be the most cost effective option. Requirements for periodic maintenance and the associated costs are addressed. In addition, suggestions for basin-wide erosion control measures are included.

1.2 OBJECTIVES

The main objectives of the Lake Shafer feasibility study are to perform a bathymetric survey of the lake in order to ascertain the present lake storage capacity, estimate the past, present, and future rates of lake sedimentation, identify potential sources of sediments and evaluate feasible sediment control methods. The objective of this study also includes development of a sediment control plan and maintenance program to minimize the rate of lake sedimentation. This study is limited to Lake Shafer proper.

1.3 SCOPE OF WORK

The scope of work for the Lake Shafer Feasibility study was described in K & S Testing and Engineering's proposal. Specifically, the scope of work for this study includes the following:

Survey of lake cross-sections to estimate present storage capacity of the lake

Sediment Sampling

Soil Laboratory Testing

Data Review

Sedimentation Analysis

Evaluation of Sediment Traps

Develop Disposal and Maintenance Programs

Prepare Cost Estimate

Prepare Final Report

The extent of the study area was limited to the main lake body including portions of the major tributaries like the Tippecanoe River, Big Monon Creek, Hoagland Bay, and Honey Creek, Keans Bay, and several small ditches in the immediate vicinity of the lake shore. The first phase of field sampling and survey work was completed during the month of August, 1993. There were no significant storm events during this period. Water samples collected during this period did not indicate any measurable quantities of suspended sediment loads. The flow velocities in the vicinity of the lake were too low to transport any significant quantities of bedload. Sediment transport in streams occurs by three modes, namely, rolling or sliding, saltation, and suspension. At low velocities and bed shear, sediment particles tend to roll or slide along the bed. With small increase in velocities and bed shear, particles hop up from the bed and follow ballistic trajectories. This mode of transport is known as saltation. The quantity transported by rolling or sliding and saltation is called the bed load. Many researchers have found that the suspended sediment transport constitutes about 90 to 95 percent of the total sediment load carried by a stream (Raghuvanshi, etal, 1994).

The second phase of field sampling was completed in December, 1994. The suspended sediment samples collected during this phase indicated considerable suspended sediment loads. The results of this investigation are included in subsequent sections of this report.

2.0 SEDIMENTATION ANALYSIS

2.1 DATA REVIEW AND ANALYSIS

2.1.1 Hydrologic Data

The Tippecanoe River is a tributary of the Wabash River and has a drainage area of over 1900 square miles at its mouth. The drainage area at Norway Dam is 1,732 square miles (USGS, 1979). There are three (3) U.S. Geological Survey (USGS) stream gaging stations at various locations on the Tippecanoe River. The maximum, average, and minimum flows of record at different locations along the stream course are abstracted in Table 2.1. The term 30-year 1-day low flow used in Table 2.1 represents the average daily low flow which is likely to occur at that location once in 30 years.

TABLE 2.1

MAXIMUM, AVERAGE, AND MINIMUM FLOWS
OF TIPPECANOE RIVER

LOCATION	DRAINAGE AREA (SQ. MILES)	FLOWS IN CUBIC FEET PER SECOND MAXIMUM	AVERAGE	MINIMUM	REFERENCE
North Webster	49.3	364	48	0.06	USGS, 1992
Oswego	113	950	105	0.08	USGS, 1992
Ora	856	8,660	848	87	USGS, 1992
Monticello (Norway Dam)	1,732	16,800	1,493	103	USGS, 1979
Delphi	1,865	22,600	1,625	101[a]	USGS, 1979 & IDNR, 1980

[a] represents 30-year 1-day low flow

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There are a number of fresh water lakes located upstream of Lake Shafer that are tributary to the Tippecanoe River. These lakes tend to trap some of the sediment load transported by the respective streams. The drainage areas, surface areas, and storage capacities at the locations of lakes on the main stem are shown in Table 2.2 (IDNR, 1980). Estimates of the trapping efficiency of these lakes is also shown by Table 2.2. Current trap efficiencies of these lakes are not available. However, using Brune's curves (USBR, 1987) and an empirical equation relating trap efficiency with storage capacity and drainage area (Rouse, 1950), the trap efficiencies of these lakes have been estimated. The resulting values are shown in Table 2.2. Due to sedimentation over the years, the current storage capacities and trap efficiencies of these lakes are expected to be lower than the values shown in Table 2.2. As these upstream lakes lose their trapping abilities, more sediment passes into the Tippecanoe River and then is transported by storm events downstream.

TABLE 2.2

SALIENT FEATURES OF LAKES ON MAIN STEM
OF TIPPECANOE RIVER

NAME OF LAKE	DRAINAGE AREA SQUARE MILES	SURFACE AREA (ACRES)	STORAGE CAPACITY MILLION GALLONS	ACRE-FT.	(%) TRAP EFFICIENCY
Webster	49.20	774	1,906	5,850	92
James	55.90	282	2,469	7,578	93
Tippecanoe	113.00	768	9,247	28,380	96
Oswego	113.00	83	254	780	48
Shafer	1732.00	1,291	4,275	13,120	50
Freeman[a]	1792.00	1,547	8,472	26,000	59

[a] Located downstream of Lake Shafer

The recorded mean monthly and greatest daily precipitation depths for the period 1951-1980 at four (4) selected stations in the watershed of the Tippecanoe River are shown in Table 2.3 (Gale Research Company, 1985).

TABLE 2.3

RECORDED MEAN MONTHLY AND GREATEST DAILY PRECIPITATION DEPTHS IN TIPPECANOE RIVER WATERSHED (1951-1980)

MONTH	PRECIPITATION DEPTH (INCHES) DELPHI[a]	WINAMAC	ROCHESTER	GOSHEN[b]
January	1.95	1.96	1.80	1.78
February	1.88	1.71	1.63	1.58
March	2.85	2.78	2.64	2.60
April	3.79	4.07	4.07	3.59
May	3.69	3.26	3.53	2.97
June	4.14	4.51	4.27	3.61
July	4.49	3.92	3.99	3.61
August	3.75	3.84	3.43	3.66
September	2.91	3.07	3.33	3.03
October	2.46	2.57	2.62	2.73
November	2.53	2.66	2.90	2.32
December	2.53	2.61	2.46	2.23
TOTAL ANNUAL	36.97	36.96	36.67	33.71
GREATEST DAILY	6.96 (5-16-68)	4.35 (6-8-58)	4.72 (4-29-56)	4.28 (8-20-79)
GREATEST MONTHLY	11.47 (June,1958)	12.46 (June,1958)	10.32 (June,1958)	11.68 (August,1979)

[a] Station is downstream of Lake Shafer

[b] Station is approximately 20 miles north of Tippecanoe Lake

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The precipitation data shown in Table 2.3 indicate that there is no significant spatial variation of annual rainfall in the Tippecanoe River watershed.

A review of the maps (IDNR, 1980) showing erosion potential of the soils in the Tippecanoe River watershed indicates the prevalence of low to medium erosion potential. Soils in portions of the watershed in White and Pulaski counties (just upstream of Lake Shafer) have predominantly low erosion potential except in the vicinity of the floodplains of the Tippecanoe River. Soils here are reported to have medium erosion potential. Soils in portions of the watershed in Marshall and Kosciusko counties have predominantly medium erosion potential and those in Fulton County have mostly low erosion potential with some pockets with medium erosion potential (IDNR, 1980). Soils with low erosion potential are deep and very poorly to somewhat drained on nearly level and depressional lands. Those with medium erosion potential are deep and somewhat poorly drained on nearly level to slightly sloping topography.

The bed slope of the Tippecanoe River upstream of Buffalo is approximately 0.032 percent or about 1.7 ft/mi (USGS Quadrangle Maps). This indicates that the stream is not a highly eroding stream.

2.1.2 Sediment Transport Data

Most of the suspended sediment load reaching Lake Shafer is transported by the Tippecanoe River and its tributaries during high flows. The average yearly suspended sediment load of the Tippecanoe River near Ora is estimated to be 34.7 tons per square mile of drainage area (Marie and Davis, 1974). The suspended-sediment discharge to water discharge relationship and suspended-sediment duration curve for the Tippecanoe River near Ora are reproduced in Figures 2.1(a) and 2.1(b) respectively (Marie and Davis, 1974).

SUSPENDED SEDIMENT

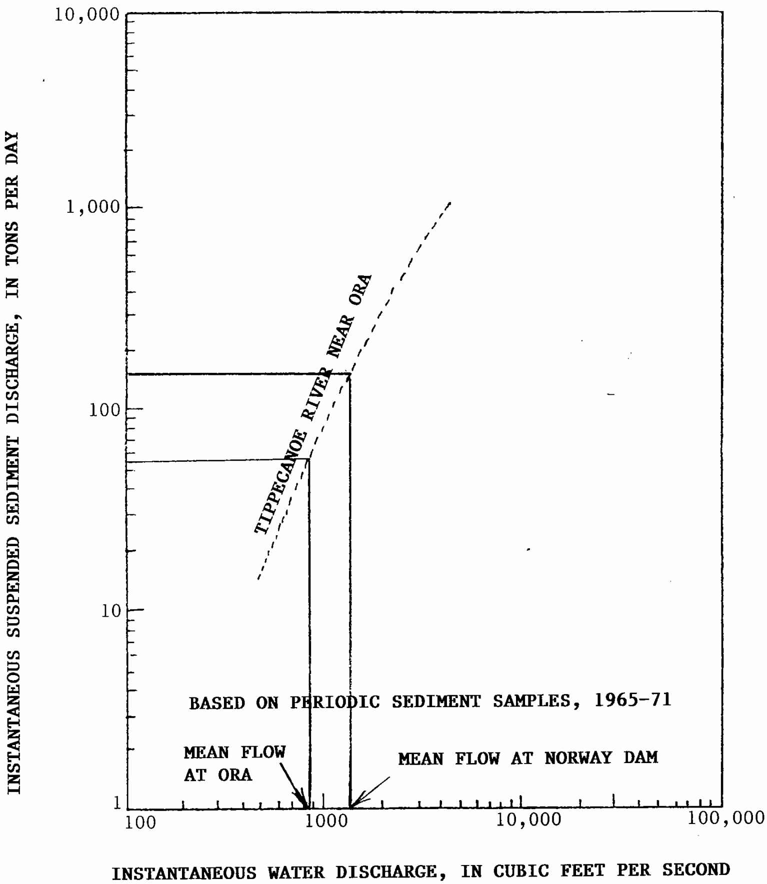

FIGURE 2.1(a) AVERAGE RELATION OF SUSPENDED-SEDIMENT DISCHARGE TO WATER DISCHARGE

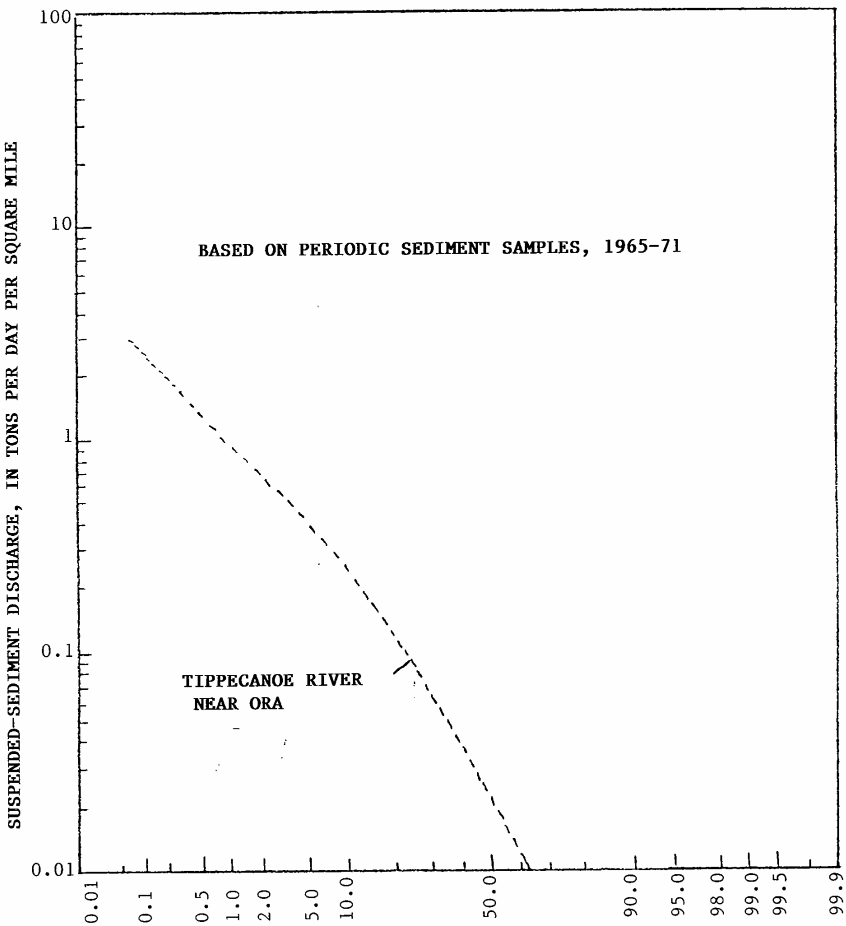

FIGURE 2.1(b) PERCENTAGE OF TIME SUSPENDED-SEDIMENT DISCHARGE WAS EQUALLED OR EXCEEDED

SUSPENDED-SEDIMENT DURATION CURVES

Figure 2.1(a) gives a relationship between streamflow in cubic feet per second (cfs) and suspended sediment transport in tons per day. The average streamflow at Ora is 848 cfs. The corresponding average suspended load from Figure 2.1(a) is about 80 tons/day. The relationship of Figure 2.1 (b) indicates that suspended sediment load of the Tippecanoe River near Ora equalled or exceeded 0.023 tons per day per square mile (ie., 20 tons/day for the entire drainage area of 856 square miles) about 50 percent of the times sediment sampling was made. Measured suspended-sediment concentration of the Tippecanoe River near Ora on March 7, 1979 was 25 mg/l resulting in a suspended-sediment transport of 378 tons/day (USGS, 1979). The discharge of the Tippecanoe River at Ora at that time was 5,600 cubic feet per second (USGS, 1979).

In an earlier study sediment samples were collected from depositional areas in Lake Shafer between Lowe's Bridge and the bridge at Buffalo, Indiana covering a river reach of 5.25 miles from approximately 4.5 miles to 9.75 miles upstream of Norway Dam (Shafer/Freeman Lakes Environmental Conservation Corporation, 1992). The sediment sizes for these depositional areas are abstracted in Table 2.4 (Alt & Witzig, 1993).

TABLE 2.4

SEDIMENT SIZES OF DEPOSITIONAL AREAS BETWEEN
LOWE'S BRIDGE AND BUFFALO BRIDGE ON TIPPECANOE RIVER

	SITE	PARTICLE SIZE IN MILLIMETERS d15	d50	d85	DESCRIPTION
1.	Just upstream of Lowe's Bridge (4.5 miles upstream of Norway Dam)	0.003	0.023	0.17	Silt
2.		0.19	0.25	0.30	Sand
3.		0.25	0.32	0.50	Sand
4.		0.27	0.33	0.86	Sand
5.		0.21	0.29	0.40	Sand
6.		0.014	0.054	0.15	Sandy Silt
7.		0.12	0.24	0.37	Sand
8.		0.34	0.57	1.70	Sand
9.		0.008	0.04	0.19	Sandy Silt
10.		0.41	0.84	1.80	Sand
11.		0.085	0.33	0.90	Silty Sand
12.	Just downstream of Buffalo Bridge (9.75 miles upstream of Norway Dam)	0.01	0.19	0.37	Silty Sand

Note: Particle sizes for clay are $\leq$ 0.005 mm; silt from 0.005 to 0.074 mm; and sand from 0.074 to 4.76 mm.

The data abstracted in Table 2.4 indicate that on the average, there is less than 1.0 to 2.0 percent clay, 2.0 to 5.0 percent silt and about 94.0 percent sand in the deposited sediments in the upper reaches of Lake Shafer.

This is corroborated by two bedload samples of the Tippecanoe River near and upstream of Lowe's Bridge collected and analyzed during the present study (Appendix A). In addition to these samples, two bedload samples of Hoagland Bay were also collected and analyzed during the present study (Appendix A). The results of these analyses are abstracted in Table 2.5.

TABLE 2.5

PARTICLE SIZES OF BEDLOAD SEDIMENTS IN TIPPECANOE RIVER AND HOAGLAND BAY
(Based on laboratory analysis in August-September, 1993)

		PERCENT				PARTICLE SIZE IN MM		
	LOCATION	GRAVEL	SAND	SILT	CLAY	d15	d50	d85
1.	Tippecanoe River upstream of Lowe's Bridge	1.0	94.0	2.0	3.0	0.18	0.33	1.30
2.	Near Lowe's Bridge	1.0	94.0	3.0	2.0	0.18	0.38	1.40
3.	Hoagland Bay near mouth at 1.5 ft. depth	0	71.0	25.0	4.0	0.03	0.14	0.33
4.	Hoagland Bay near mouth at 2.0 ft. depth	0	70.0	25.0	5.0	0.03	0.13	0.32

The bed material in Lake Shafer was classified in a 1954 sedimentation study based on random soil tests (Uhl, 1954). This report stated that the bed material consisted of sands and black silts up to depths of 6.0 to 90.0 inches at different locations.

During the course of the present study (August, 1993), suspended sediment samples were collected from Big Monon Bay, Tippecanoe River and Hoagland Bay. However, because the sampling was conducted during a non-storm low-flow period, suspended-sediment concentrations in all these samples were found to be insignificant.

Following a normal storm event, the second phase of suspended sediment measurements was completed on December 7, 1994. The sediment samples were collected at eight (8) locations on the lake and its tributaries. Sampling location map is provided in Appendix I. The samples were picked up by a representative of American Analytical, Inc. (A_2I) of Merrillville, Indiana and were analyzed for Total Suspended Solids.

Suspended sediment sampling results are tabulated below.

TABLE 2.5A

Suspended Sediment Sampling Results

LOCATION	CONCENTRATION (mg/l)
S-1, Tippecanoe River	69.0
S-2, Big Monon Ditch	436.0
S-3, Carnahan Ditch	31.0
S-4, Lake Shafer (Near Lowe's Bridge)	21.0
S-5, Big Monon Bay	19.0
S-6, Hoagland Bay	256.0
S-7, Keans Bay	30.0
S-8, Honey Creek Bay	184.0

The measured water flow rate during the suspended sediment sampling as reported by NIPSCO at Norway Dam was 2250 cubic feet per sec. Using this flow rate, the suspended sediment load that entered Lake Shafer on the day of sampling through the streams listed in Table 2.5A is estimated to be approximately 445 tons/day or 0.243 acre-ft/day. This sediment load does not include the bedload which is about 10.0 percent of the total load. The total estimated sediment load that entered Lake Shafer on December 7, 1994, including bedload, is approximately 500 tons/day or 0.267 acre-ft/day. Analytical results along with chain-of-custody form are included in Appendix I.

The above mentioned suspended sediment samples were collected near the mouths of respective tributaries. It is possible that some of the sediment transported by these relatively flat streams may have deposited before it reached the mouth. Thus, the measured suspended sediment load at the mouth may be less than what may appear farther upstream. Suspended sediment measurements farther upstream of the mouths of the tributaries is beyond the scope of work. It is possible that during severe storm events, the loose sediments deposited above the mouth may find its way into Lake Shafer.

2.2 LAKE SEDIMENTATION

2.2.1 Review of Past Lake Sedimentation Data

At the time of construction Lake Shafer is reported to have had a storage capacity of 14,722 acre-ft (Strange, 1986). The watershed upstream of the lake is reported to be characterized by a predominance of black, carbonaceous silt deposits. As a result sheet erosion has been more pronounced than gullying (Uhl, 1954). A report on Lake Shafer sedimentation in 1954 documented that the rate of lake sedimentation exclusive of Honey Creek, Hoagland Creek and Monon Creek basins was approximately 20.0 acre-ft per year or a total of about 600 acre-ft from 1924 to 1954 (Uhl, 1954). Other significant observations included in this report are summarized below:

The average depth of sedimentation in the exposed lake area between elevation 645.0 and 631.0 feet was about 6.0 inches or less.

Honey Creek (drainage area = 40.0 square miles) above the bridge (County Highway Bridge #90) crossing formed a settling basin and had trapped about 8.0 acre-ft of sediment.

There are several small creeks entering Lake Shafer from both sides that have drainage areas of about one square mile. Sedimentation in these creeks were estimated to be about 0.33 acre-ft. This sediment deposition was observed at the mouth of the channel. Keans Creek is the largest of this group of channels. The amount of sedimentation in this creek was not estimated (Uhl, 1954).

Hoagland Ditch (drainage area = 70.0 square miles) served as a catch basin upstream of the bridge crossing. Observation shows silting has occurred to a depth of approximately 14.0 feet in this basin. However, an exact volume of sedimentation was not determined.

Big Monon Creek (drainage area = 70.0 square miles) exhibited no significant silting. The estimated depth of silting was 6.0 to 8.0 inches.

Ketman Ditch (Big Monon Ditch) which flows from the sand dune areas north of Lake Shafer carried considerable amount of sediment load during high flows.

Another sediment survey of Lake Shafer was conducted in August, 1983 (Strange, 1983). The purpose of this Strange's study was to estimate the loss of lake capacity during the period 1959 to 1983. During this survey, water depths were measured at various locations in the lake. No computations were made to estimate the volume of lake sedimentation. The results of the surveys were divided into four reaches of the lake. The averages of the measured water depths in these reaches are shown in Table 2.7. The corresponding water depths computed from the 1959 surveys and the loss of depth from 1959 to 1983 are also shown in Table 2.7.

TABLE 2.7

AVERAGE WATER DEPTHS IN LAKE SHAFER IN 1959 AND 1983

REACH	WATER DEPTH IN FEET 1959	1983	LOSS OF WATER DEPTH FEET	LOSS IN FT/YEAR
Hoagland Bay to Big Monon Creek	13.8	9.4	4.4	0.18
Big Monon Creek to Lowe's Bridge	11.2	4.1	7.1	0.30
Lowe's Bridge to Carnahan Ditch	8.6	4.4	4.2	0.175
Carnahan Ditch to Big Monon (Ketman) Ditch	7.2	5.7	1.5	0.063

The results shown in Table 2.7 indicate that maximum sedimentation occurred in the reach from Big Monon Creek to Lowe's Bridge. This is in agreement with the observation in the 1954 survey that Ketman Ditch (Big Monon Ditch) carried considerable amounts of sediment load. Sedimentation in the reach between Carnahan Ditch and Big Monon (Ketman Ditch) was relatively small.

The U.S. Department of Agriculture Miscellaneous Publication Number 1362, Records from Sediment Deposition in U.S. Reservoirs (Summary of Data Reported through 1975) reports the changes in storage capacities shown in Table 2.6 (Strange, 1986).

TABLE 2.6

HISTORIC VARIATIONS IN STORAGE CAPACITY OF LAKE SHAFER

DATE OF SURVEY	STORAGE CAPACITY ACRE-FT	CUMULATIVE LOSS ACRE-FT	SEDIMENTATION INCREMENTAL ACRE-FT	RATE ACRE-FT/YR
June, 1923	14,722	0	0	0
August, 1940	14.041	681	681	40
May, 1960	13,118	1,604	923	46
Nov., 1986	10,966[a]	3,756	2,152	82.8

[a]computed by Strange (1986)

The 1986 value for cumulative sedimentation, ie., 3756 acre-ft is based on the following assumptions (Strange, 1986):

> The lake area was exposed between elevation 648.0 and 632.0 feet; the thickness of sediment deposition in these areas was estimated by hand probing with sectional steel probes at representative locations. This means that sedimentation in lake area below EL 632.0 ft. was not surveyed and the thickness of deposited sediment was estimated by feeling that the probe has struck natural ground below loose sediment deposits.

A shape factor of 0.25 to 0.75 was used by judgement to convert the estimated thickness of the deposits at the location of the probe to average thickness for that portion of the deposit. Since the bottom surface of the deposit could not be seen, the shape factor was based on the appearance of the top surface only. This accounts for the possibility that the thickness of deposited sediments may be less than measured at locations away from the point of measurement.

The area of lake bed below elevation 632.0 feet (ie., between elevation 618.0 and 632.0 feet) was assumed to have 1.0 foot deep silt deposition.

The estimated volumes of sediment deposition in different portions of the lake are abstracted in Table 2.8 (Strange, 1986).

TABLE 2.8

ESTIMATED VOLUMES OF SEDIMENT DEPOSITION IN LAKE SHAFER (IN NOVEMBER, 1986)

LOCATION	ESTIMATED VOLUME ACRE-FT	SHAPE FACTOR[a]
Norway Dam	17.3	0.50
Honey Creek Bay	127.2	0.50 to 0.75
Indiana Beach	61.3	0.50
Keans Bay	59.1	0.50
Hoagland Bay	266.4	0.50 to 0.75
Big Monon Bay	1,706.6	0.50 to 0.75
Lowe's Bridge	566.7	0.50 to 0.75
Carnahan Ditch	359.4	0.50 to 0.75
Big Monon Dredge Ditch	50.1	0.25
Remainder of Channel Area (Approx. area = 542.0 acres)	542.0	1.0
TOTAL	3,756.1	

[a]It is a judgmental factor used to convert the thickness at the location of the probe to an average thickness for the deposition around that point

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Since the construction of the dam and inception of recreation activities in the lake, local residents have removed unknown quantities of sediments at various times from different portions of the lake area to maintain sufficient water depth for the movement of their boats. This quantity of sediment is not reflected in the estimates described in this section. Thus, the estimated sedimentation rate may be somewhat on the lower side.

2.2.2 Present Storage Capacity Information

To estimate the present (August, 1993) storage capacity of Lake Shafer, the entire lake including the tributaries was divided into 64 transects. The locations of these transects along with the lake bottom contours are shown on Figure 2.2 (see Appendix B). Each cross-section was surveyed by taking soundings at various locations using a boat and a graduated staff. The water surface elevation at each cross-section at the time of the surveys was determined with reference to a permanent USGS Benchmark (G126, elevation 657.436 feet) located near State Road 16. The shoreline (water surface) elevations and soundings with the respective distances from the shoreline are included in Appendix B.

Using the cross-sectional information included in Appendix B and the distances between adjacent transects, the storage capacity of the lake has been estimated. Details of these computations are included in Appendix C. The estimated storage capacities for different portions of the lake are abstracted in Table 2.9.

At the time of surveying, the lake water surface was frequently disturbed by boat traffic and wind waves. Also, the silt-laden and loose lake bottom made it difficult to place the bottom tip of the staff exactly at the top of the bottom sediments. Thus measurement of water depths involved subjective judgement. It is estimated that the aforementioned factors may have resulted in an error of approximately ±5 percent in depth measurements. Therefore, it appears reasonable to assume that the storage capacities shown in Table 2.9 may have an error band of about ±5 percent.

TABLE 2.9

STORAGE CAPACITY OF LAKE SHAFER IN AUGUST 1993

REACH	STORAGE CAPACITY ACRE-FT.
Tippecanoe River (transects 1-22, from Lowe's Bridge to Route SR-16, over a reach length of 18,500 feet)	1,141.9
Lake Shafer (transects 23-33, 37-41 and 45-47 from Norway Dam to Lowe's Bridge)	6,732.8
Keans Bay (transects 34-36)	181.8
Honey Creek Bay (transects 42-44)	201.9
Hoagland Bay (transects 48 and 66)	14.4
Big Monon Bay (transects 49-51, 53-54, 56, and 59-64)	1,171.9
TOTAL	9,444.7

The total storage capacity of Lake Shafer and portions of the above mentioned tributaries was estimated to be 9,445 acre-feet. This volume reflects a significant loss of 1,521 acre-ft since 1986 resulting in an annual average sedimentation rate of 217 acre-ft per year and a cumulative lake sedimentation of 5,277 acre-ft with an annual average rate of 75 acre-ft/year from 1923 to 1993. This suggests that there has been a significant increase in the rate of sedimentation during the past 7 years or so.

2.2.3 Sedimentation Rates

The variation in the storage capacity of Lake Shafer with respect to time is shown in Figure 2.3 (a). The increases in lake sedimentation and rates of sedimentation with respect to time are shown in Figure 2.3 (b). Note that the rate of lake sedimentation increased from about 40.0 acre-ft/year during the first 17 years (1923-1940) to 217 acre-ft/year during the past 7 years and approximately 29 percent of the total sedimentation (for a lake life of 70 years) occurred during these 7 years (1986-1993).

An empirical relationship (see Appendix J) developed by the Bureau of Reclamation (USBR, 1987) based on data from 28 reservoirs in semi-arid climate gives an average annual potential sediment yield of 532 acre-ft/year from the 1,732 square miles drainage area upstream of Norway Dam. Assuming that the drainage areas upstream of the lakes in the upper watershed do not contribute any significant sediment inflow to Lake Shafer, average annual potential sediment yield from the remaining area of 1,619 sq. miles is estimated to be about 506 acre-ft/year. Since the watershed is located in a subhumid region, the actual sediment yield is expected to be somewhat lower than the above value which refers to semi-

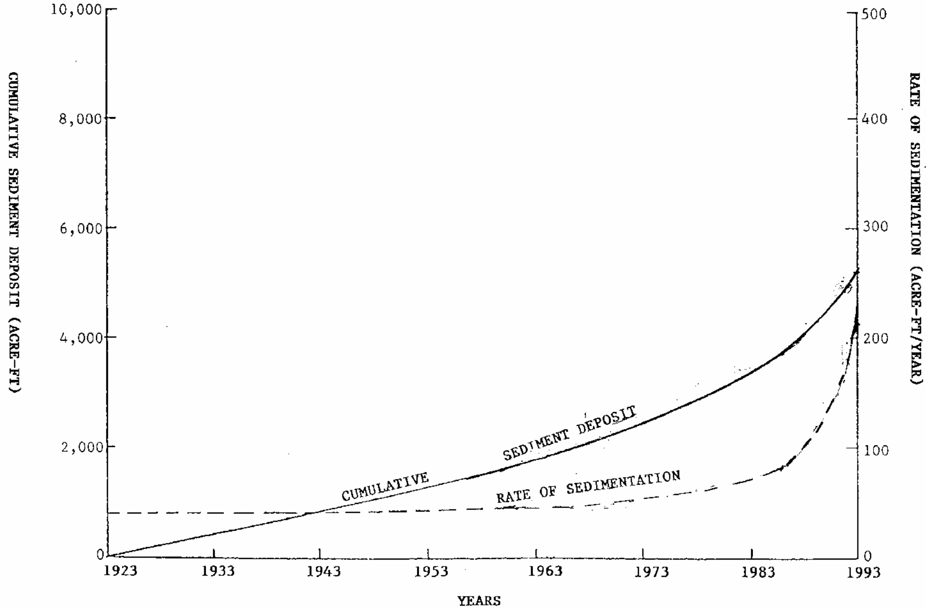

FIGURE 2.3(b) CUMULATIVE DEPOSITION AND RATE OF SEDIMENTATION FOR LAKE SHAFER

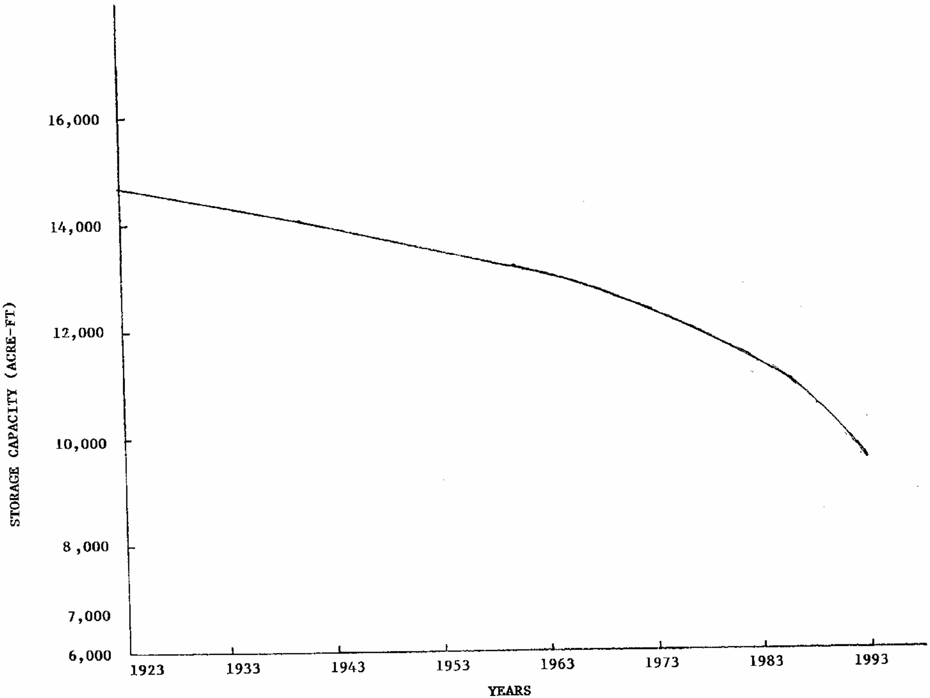

FIGURE 2.3 (a) VARIATION OF STORAGE CAPACITY OF LAKE SHAFER WITH TIME

arid climates. Based on a summary of reservoir sediment deposition in the United States, the lower and upper ranges of potential rates of sedimentation from the contributing drainage area of 1,619 sq. miles for Lake Shafer are estimated to be 300 to 1,280 acre-ft./ year (Golze, 1977).

The annual sedimentation rate (217 acre-ft/year) estimated from the 1993 lake surveys is below the above range. However, this investigation indicates a significant increase in the rate of sedimentation over the past seven years. The following items may account for the recent increase in the sedimentation rate of Lake Shafer.

> The previous estimates of lake sedimentation were based on point measurements of sediment thicknesses within the exposed areas of the lake, ie., within the top 47 to 53 percent of the total lake depth. Generalized sediment distribution design curves (USBR, 1987) indicate that the remaining (unexposed) portion of Lake Shafer during the previous surveys could contain 18 to 23 percent of the total sediment deposited in the lake. This suggests that the previous volumes of sedimentation may be somewhat under-estimated.
>
> The area of the lake covered by the present survey (1993) is about 1,120 acres. This is less than the reported lake area of 1,291 acres (Strange, 1983) and 1,193.8 acres (Strange, 1986) used in earlier studies. Therefore, the lake storage capacity computed from the 1993 survey may be somewhat under estimated resulting in a relatively higher estimate of sediment deposition.

Due to increasing boat traffic in the lake, boat-generated waves may have caused increased shore erosion (bank failure) during the past seven years or so resulting in a relatively higher rate of lake sedimentation.

Increased disturbance and development in the watershed, reduced trap efficiencies of the upstream lakes, and inadequate soil conservation practices may have contributed to increased rates of lake sedimentation.

Since 1986 depressional areas acting as sediment traps may have been filled naturally by development thus losing their effectiveness resulting in additional sedimentation of the lake. More frequent ice flows gouging sediments from river and stream banks as well as the shoreline of Lake Shafer may be contributing to the increased rate of sedimentation.

The average sedimentation rate over the life of Lake Shafer (1923-1993) is estimated to be 75 acre-ft/year or 0.046 acre-ft/sq. mile per year (assuming the contributing drainage area to be 1619 sq. miles). The corresponding sedimentation rate during the past 7 years (1986-1993) is 0.134 acre-ft/sq. mile per year. Typical rates for reservoirs in humid regions with similar size watersheds are reported to be 0.20 to 0.80 acre-ft/square mile per year (Golze, 1977). Compared to the sedimentation rates of reservoirs for which published information is available, the above rate is about 17 to 67 percent. However, the relatively faster rate of lake sedimentation during the past decade is a cause of concern for continued recreational use of the lake.

2.2.4 Potential Sources of Sedimentation

About 75 percent of the annual suspended sediment load of the Tippecanoe River at Ora is transported during flows which exceed the median daily flow of 500 cfs (Marie and Davis, 1974). Suspended sediment load samples collected from the tributaries during low flow conditions in August, 1993 indicated negligible suspended sediment transport. Second phase of suspended sediment sampling conducted in December 1994 during a significant storm event indicated considerable suspended sediment transport as shown in Table 2.5A.

This suggests that even in the vicinity of Lake Shafer, most of the suspended sediment transport occurs during high flow conditions. However, bedload transport may continue throughout the year. The main tributaries carrying sediment load into the lake body are:

Tippecanoe River (from North),
Drainage Are = 1,732 sq mi

Honey Creek (from West),
Drainage Area = 40 sq mi

Keans Bay (from East)
Drainage Area = 20 sq mi

Hoagland Bay or Hoagland Ditch (from West),
Drainage Area = 70 sq mi

Big Monon Creek (from West),
Drainage Area = 70 sq mi

Big Monon Ditch or Ketman Ditch (from West)
Drainage Area = 184 sq mi

Other small tributaries (e.g. Williams, Timmons, and Carnahan Ditch from the east and Harp Ditch from the west)

In addition, sheet and rill erosion from developed, undeveloped, agricultural and forested areas directly draining into the Tippecanoe River and Lake Shafer contribute to lake sedimentation. Shore erosion resulting from wind and boat generated waves is also a source of lake sedimentation.

2.3 Estimation of Future Rate of Sedimentation

In the event of no action, lake sedimentation will continue to reduce the usable area of lake surface for recreation and increase the area of flooding along the lake shore during floods and ice jams. With limited information about the accuracy of previous lake sedimentation surveys, it is not possible to determine the exact amount of sedimentation that has occurred during the recent (past five) years. The 1993 survey is based on 64 lake cross-sections and is believed to reflect the present (1993) storage capacity of the lake within an error band of ±5 percent. This survey indicates that the average rate of lake sedimentation over the past 70 years has been 75 acre-ft/year with a significantly higher average annual sedimentation rate of 217 acre-ft/year during the past 7 years (1986-1993).

Annual rates of sedimentation for three other streams in Indiana are reported to be 393 tons/square mile for Deer Creek near Delphi, 227 tons/square mile for Wildcat Creek near Lafayette and 233 tons/square mile for Wabash River near Lafayette (Marie and Davis, 1974). Assuming the unit weight of sediments to be about 85.8 lbs/c ft (Section 3.1.2), the annual sedimentation rates for these three streams range from 0.12 to 0.21 acre-ft/square mile. Compared to this, the average annual sedimentation rate of Lake Shafer has been 0.046 acre-ft/sq. mile for the 70-year period (123-1993 and 0.134 acre-ft/sq. mile for the period of 1986-1993.

In view of the above, it appears reasonable to assume that, if no remedial actions are taken, then the future rate of sedimentation for Lake Shafer may be about 217 acre-ft per year (Section 2.2.3). At this rate, the loss of lake capacity is estimated to be as shown in Table 2.10.

TABLE 2.10

POSTULATED LOSS OF LAKE SHAFER STORAGE CAPACITY

YEAR	STORAGE CAPACITY ACRE-FT	ANTICIPATED SEDIMENT DEPOSITION ACRE-FT SINCE 1993	SINCE 1923
1993	9,445	0	5,277
1995	9,011	434	5,711
1997	8,577	868	6,145
1999	8,143	1,302	6,575
2001	7,709	1,736	7,013
2003	7,275	2,170	7,447
2013	5,105	4,340	9,617

If no sediment control measures are adopted, then the lake capacity may be reduced to about 49 percent of the original by the year 2003 and to about 35 percent by the year 2013 at the current estimated sedimentation rate of 217 acre-ft/year.

3.0 SEDIMENT CONTROL METHODS

3.1 SEDIMENT TRAPS

3.1.1 General

One of the methods to reduce the rate of lake sedimentation is to dredge the depressions in tributary streams which have been silted up over time. The restoration of these depressions will trap portions of the sediment loads transported by the respective streams.

Potential sites for such sediment traps include the mouths of tributaries to Lake Shafer where an existing bridge provides a constricted outlet. Such tributary streams include Hoagland Bay, Honey Creek, Big Monon Bay, Big Monon Ditch, an un-named ephemeral stream entering the lake northeast of Big Monon Ditch, and Carnahan Ditch. The other tributaries, viz., Timmons Ditch, Williams Ditch and Keans Bay do not have a constricted outlet and so are not considered suitable for the construction of sediment traps. The recently surveyed (1993) cross-sections of Big Monon Bay (Appendix B Transects 49-51, 53-54, 56, 59, 60 & 60A) indicates no significant sedimentation in this stream. The absence of significant sedimentation in this channel was reported in earlier studies as well (Uhl, 1954; Strange, 1983). This suggests that this stream does not transport any appreciable amount of sediment load and so construction of a sediment trap at its mouth may not reduce sediment entry in Lake Shafer. However, if warranted by future field conditions, submerged weirs may be constructed near the mouths or upstream of the mouths of these streams to trap sediment before it enters Lake Shafer. Big Monon Ditch is a relatively narrow channel with no embayment at its mouth.

Therefore, it also may not be a suitable site for a sediment trap. However, a trap could be located farther upstream beyond the area covered in the scope of this study. It is possible that sediment is being transported into Big Monon Bay by rolling along its bed. This sediment may not reach the lake bed until the bay is significantly constricted. Thereafter, during a major storm, a slug of sediment may reach the lake. This situation could be alleviated by the above mentioned trap.

Construction of sediment traps with or without submerged weirs near the mouths of tributaries entering the lake is likely to control a relatively small portion of the total sediment reaching Lake Shafer. However, construction and periodic clearance of such strategically located sediment traps may be of great benefit to residents in the immediate vicinity. Properly maintained sediment traps will increase the water depth and surface area available for maneuvering private boats right up to the edges of on-shore residences located on either side of the tributaries.

The sites where sediment traps may be beneficial include the following:

Hoagland (Hoagland) Bay upstream of bridge (County Highway Bridge #91) crossing

Honey Creek upstream of bridge (County Highway Bridge #90) crossing

Carnahan Ditch upstream of bridge crossing (environmentally unacceptable site)

The locations of these sediment traps are shown in Figure 3.1 (see Appendix F).

The quantity of sediment transported by the above mentioned tributaries from year to year is a function of the soil erodibility, watershed slopes, types of surface soils, vegetal cover and intensities and durations of storms occurring in the respective watersheds during a particular year. It is not possible to predict the number, intensities and durations of storms likely to occur in a particular year in the future. To approximate the sediment yields of the watersheds of these streams and anticipated trap efficiencies of proposed sediment traps, the following assumptions are made:

> It is known that a major portion of the total annual sediment transport occurs during storm events. To simulate anticipated future recurring storm events, it is assumed that two (2) 24-hour storms with rainfall depths equal to the two-year event contributing about 15.0 percent of the total annual precipitation occur each year. The remaining 85.0 percent of annual precipitation is assumed to occur in the form of light rainfall. The 24-hour two-year precipitation depth is estimated to be 2.83 inches (US DOC, 1961). The mean annual precipitation in the watershed is about 36.08 inches (Table 2.3). The selected 24-hour storm is assumed to follow Soil Conservation Service Type II distribution, (Univ. of Kentucky 1981).
>
> The time of concentration and soil conservation service curve numbers for each watershed are selected by accepted methods of judgement. The soil loss parameters are selected so that the two (2) postulated storms produce about 90.0 to 96.0 percent of the estimated annual sediment yield from a particular watershed.

The proposed size and estimated cost for each sediment trap are presented in the following paragraphs.

3.1.2 Sediment Trap on Hoagland Bay upstream of Bridge Crossing

This sediment trap will extend up to 1,600.0 feet upstream of the bridge crossing. A cross-section of the bay at its mouth near the bridge crossing is shown in Figure 3.2 (a). A typical cross-section of the existing and proposed basin, 330.0 feet upstream of the bridge is shown in Figure 3.2 (b). A plan of the proposed basin is shown in Figure 3.2 (c). Using this information, the surface area of the proposed basin has been estimated at different elevations (see Table 3.1).

The outlet of the basin is through the bridge. The total clear opening at this location is estimated to be about 80.0 feet. The bed elevation at this location is 639.0 feet. Assuming that Lake Shafer is maintained at EL. 648.0 feet, an outflow rating table has been developed for this outlet using the following equation (Lewitt, 1958):

$$Q = 214\ h^{3/2} + 2889 \sqrt{h} \qquad (3.1)$$

where Q = outflow in cfs,

h = difference in head in the basin and Lake Shafer in feet

To account for irregular bed geometry at the outlet, a discharge coefficient of 0.50 is used in Eq. 3.1 in place of 0.62 used for orifices and weirs. The discharge rating for this outlet is shown in Table 3.1

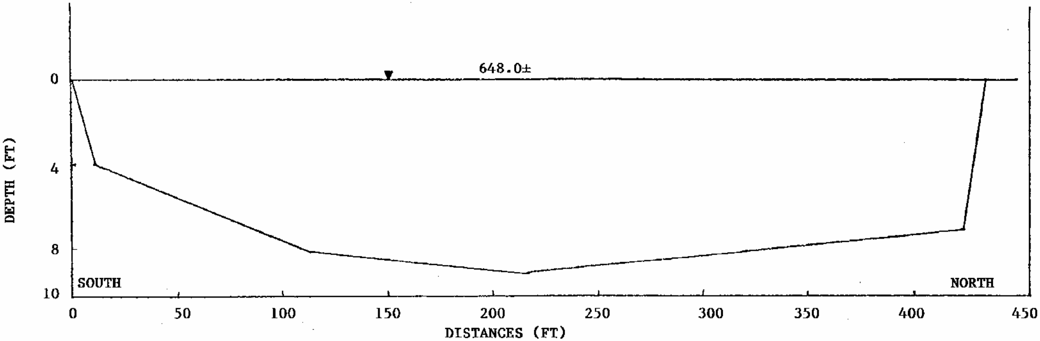

FIGURE 3.2 (a) CROSS-SECTION AT MOUTH OF HOAGLAND BAY (#48)

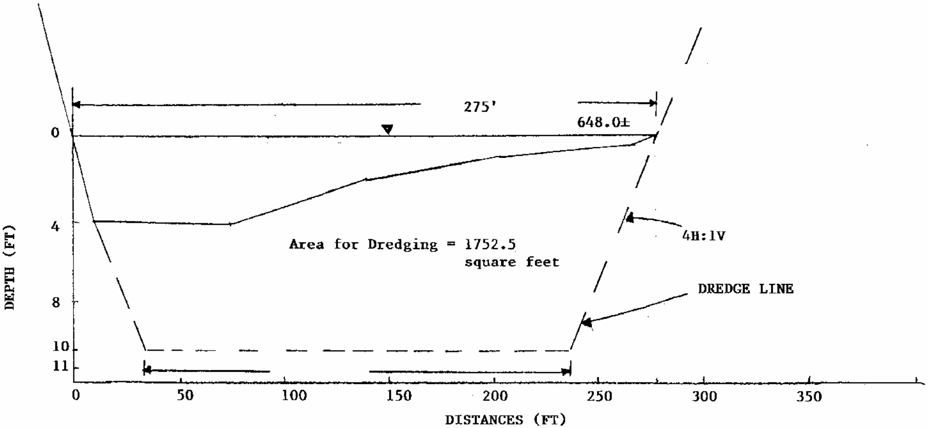

FIGURE 3.2 (b) TYPICAL CROSS-SECTION OF HOAGLAND BAY (#66)

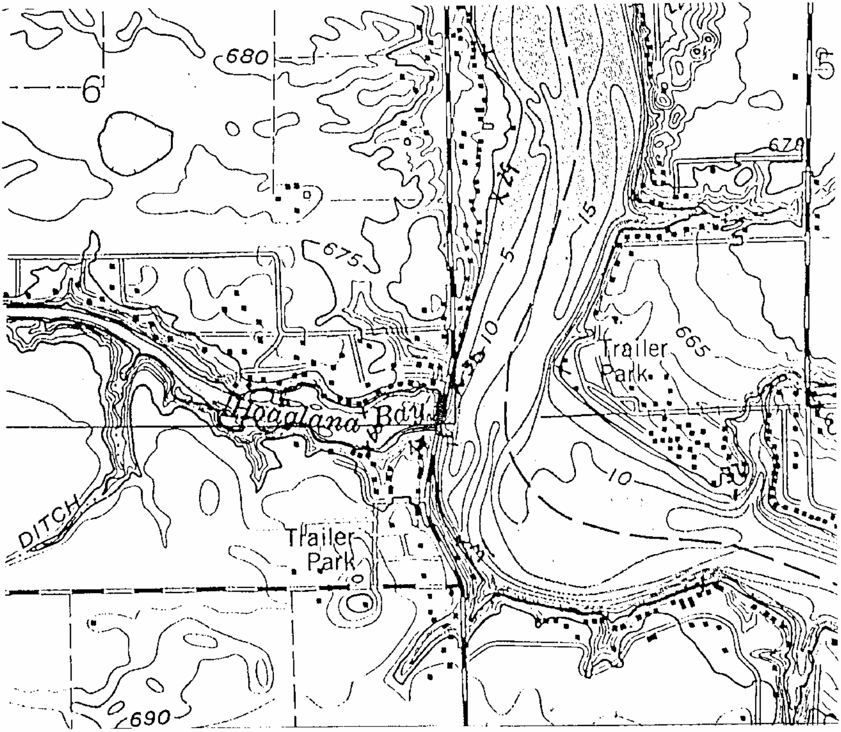

FIGURE 3.2 (c) PLAN OF SEDIMENT TRAP ON HOAGLAND BAY

TABLE 3.1

ELEVATION - AREA AND RATING TABLE FOR HOAGLAND BAY

ELEVATION (FT)	STAGE (FT)	SURFACE AREA (ACRES)	OUTFLOW (CFS)
638.0	0	0	0
640.0	2.0	3.84	0
642.0	4.0	7.96	0
644.0	6.0	8.55	0
646.0	8.0	9.13	0
648.0	10.0	9.63	0
650.0	12.0	10.10	4,690.0
652.0	14.0	10.57	7,490.0
653.5	15.5	10.87	9,535.0

Particle size distribution for two (2) bed material samples for Hoagland Bay are abstracted in Table 3.2 (Appendix A).

TABLE 3.2

PARTICLE SIZE DISTRIBUTIONS FOR BED MATERIAL
OF HOAGLAND BAY

Size (mm)	14.8	2.0	0.41	0.17	0.074	0.037	0.025	0.013
Percent Finer Sample 1	100.0	98.0	94.0	60.0	30.0	17.0	12.0	10.0
Percent Finer Sample 2	100.0	98.0	94.0	58.0	29.0	17.0	13.0	9.0

Size (mm)	0.010	0.007	0.003	0.002	0.001	0.0001
Percent Finer Sample 1	9.0	7.0	6.0	4.0	0.1	0.01
Percent Finer Sample 2	8.0	6.0	4.0	3.0	0.1	0.01

In the absence of specific information about the grain size distribution of soils in the watershed, the particle size distribution of Table 3.2 are assumed to characterize the surface soils. On an average, there is about 7.0 percent clay ($d_{50} \leq 0.005$mm), 23.0 percent silt (0.005mm $< d_{50} <$ 0.074mm), and 70.0 percent sand (0.074mm $< d_{50} <$ 4.76mm) in these soils. Assuming the unit weights of clay, silt and sand to be 26.0, 70.0, and 97.0 lbs/c ft, respectively, the unit weight of sediments is estimated to be 85.8 lbs/c ft (USBR 1987). Using the cross-section in Figure 3.2(b) as the basis, the volume of dredging for this trap is estimated to be 104,000.0 cubic yards.

To evaluate the effectiveness of this sediment trap, the SEDIMOT-II model (Univ. of Kentucky 1981) was used to simulate sedimentation during the aforementioned storm event. The results of this simulation are abstracted in Table 3.3

TABLE 3.3

RESULTS OF SEDIMOT-II SIMULATION FOR
HOAGLAND BAY SEDIMENT TRAP

VARIABLE	UNITS	VALUE
Drainage Area	sq miles	70.0
Inflow Peak	cfs	1,380.0
Peak Stage	ft	648.6
Total Inflow	acre-ft	1,024.4
Total Sediment Yield	tons	2,740.75
Trap Efficiency	percent	27.0
Storage Capacity at EL. 648.0	acre-ft	68.6
Storage Capacity at EL. 642.0	acre-ft	15.6
Storage Capacity at EL. 640.0	acre-ft	3.8

The average sediment deposition in Lake Shafer has been 75.39 acre-ft/year or 0.0435 acre-ft/sq mi/year. Assuming this rate of sedimentation, Hoagland Bay is estimated to receive about 3.0 acre-ft or 5,690.0 tons of sediment per year. The occurrence of two (2) storms of the type analyzed in Table 3.3 in a year may constitute about 96.0 percent of the total annual sediment yield. The normal situation will be somewhat less severe. Using the trap efficiency of 27.0 percent, the basin is likely to trap about 0.81 acre-ft per year. To maintain reasonable trap efficiency, it may be advisable to limit deposition in the basin to no more than

4.0 ft. above the bed, ie., no more than 15.6 acre-ft. This will require maintenance dredging every 20.0 years. The trap efficiency of the basin is likely to reduce over time with sediment deposition in the basin during the interval between two (2) successive dredging operations. Even though, the trap efficiency of 27 percent appears low, it will help in alleviating the problems of local residents at a relatively low cost.

The input and output of a typical SEDIMOT-II computer simulation are included in Appendix D.

3.1.3 Sediment Trap On Honey Creek

This sediment trap will extend up to 1,600 feet upstream of the bridge crossing. A cross-section of the creek just downstream of the bridge crossing is shown in Figure 3.3 (a). Two (2) typical cross-sections at 400.0 and 1,200.0 feet, respectively, upstream of the bridge crossing prepared from the Monticello North, USGS Quadrangle Map (photo revised 1986) are shown in Figures 3.3 (b) and 3.3 (c) and a plan of the proposed basin is shown in Figure 3.3 (d). During the construction of this sediment trap, care should be taken so that there are no modifications or disturbances to the forested riparian corridor that begins at the upstream end of the site.

The bed elevation near the outlet (at bridge crossing) is approximately 644.0 feet [Figure 3.3 (a)] and the bridge opening is about 80.0 feet. Assuming the normal pool elevation in Lake Shafer to be 648.0 feet an outflow rating table has been developed using the following equation (Lewitt 1958):

$$Q = 214\ h^{3/2} + 1284\sqrt{h} \qquad (3.2)$$

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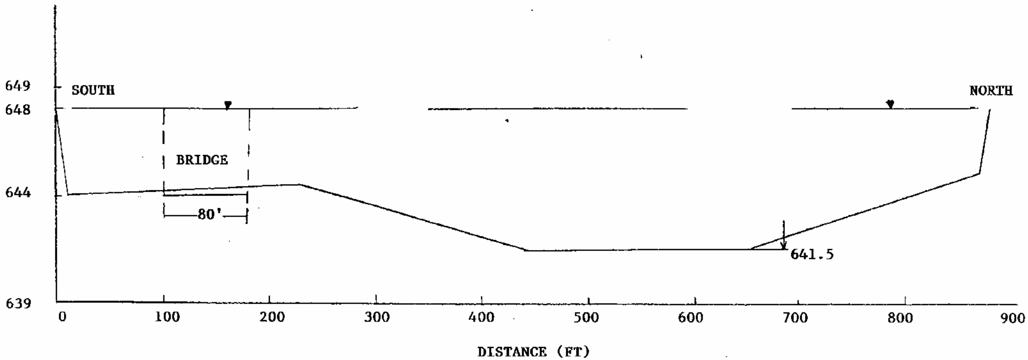

FIGURE 3.3 (a) HONEY CREEK CROSS-SECTION D/S OF BRIDGE (TRANSECT NO. 44) 1993 SURVEY

HONEY CREEK

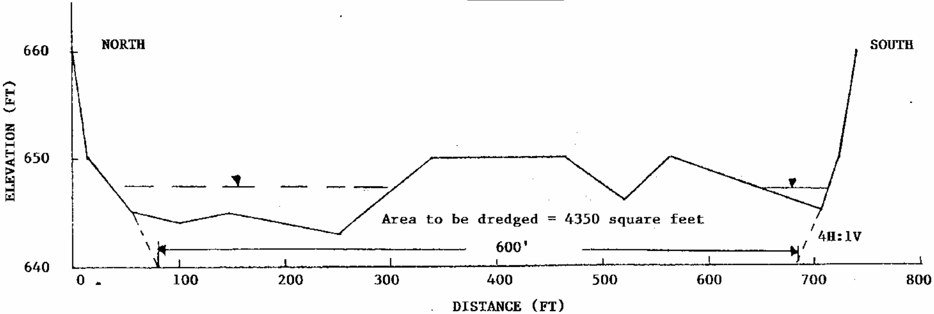

FIGURE 3.3 (b) CROSS-SECTION 400 FEET U/S OF BRIDGE (USGS QUADRANGLE)

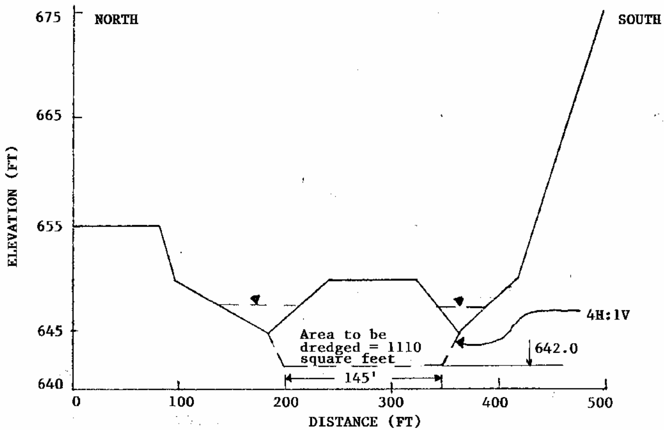

FIGURE 3.3 (c) HONEY CREEK CROSS-SECTION 1200 FEET U/S OF BRIDGE

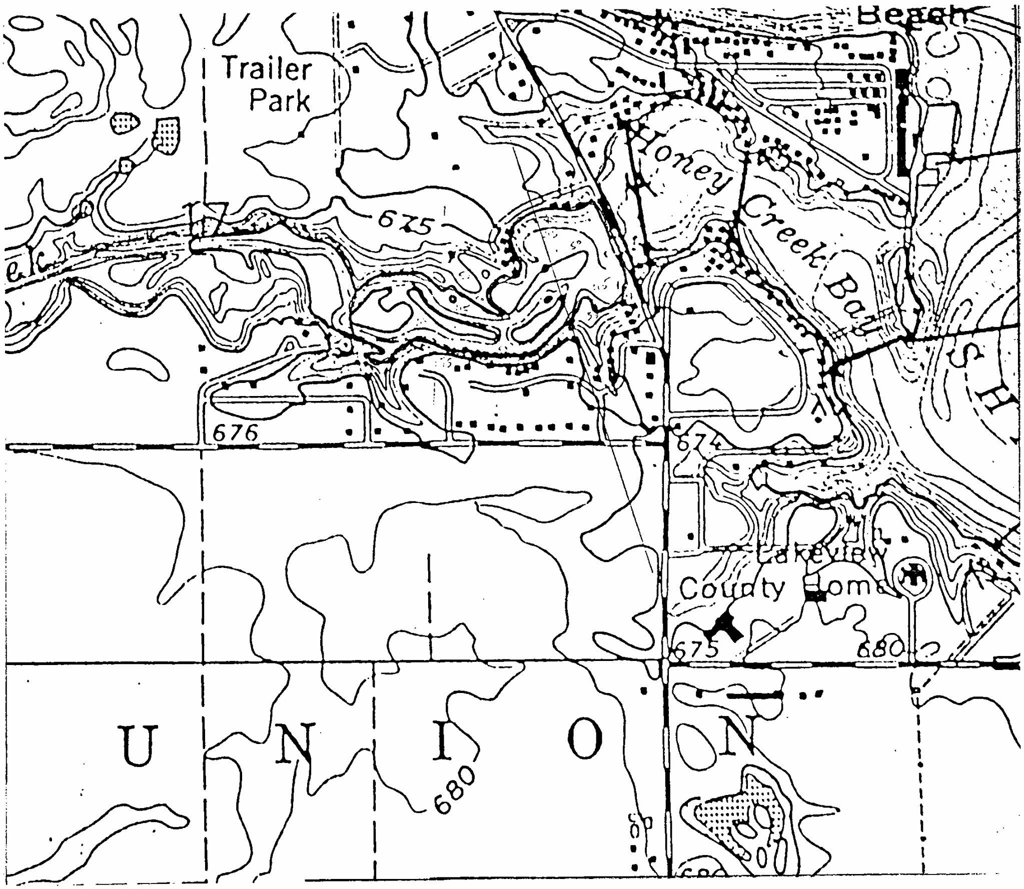

FIGURE 3.3 (d) PLAN OF SEDIMENT TRAP ON HONEY CREEK

The symbols in Equation 3.2 are the same as defined for Equation 3.1. Using the cross-sections in Figures 3.3 (b) and 3.3 (c), an elevation-area table has been prepared for this basin. The outflow rating and elevation-area tables are shown in Table 3.4

TABLE 3.4

ELEVATION-AREA AND RATING TABLE FOR HONEY CREEK

ELEVATION (FT)	STAGE (FT)	SURFACE AREA (ACRES)	OUTFLOW (CFS)
639.0	0	0	0
640.0	1	5.51	0
642.0	3	12.64	0
644.0	5	14.64	0
646.0	7	15.79	0
648.0	9	17.26	0
650.0	11	18.88	2,421
653.0	14	19.38	5,264

In the absence of specific information about the grain size distribution of sediments in this watershed, the data presented in Section 3.1.2 were used to evaluate the effectiveness of this sediment trap. The results of SEDIMOT-II simulation for a single storm event are abstracted in Table 3.5. The ratio of storage capacity to total inflow for this basin is longer than Hoagland Bay. Therefore, its trap efficiency is higher than the trap on Hoagland Bay.

K&S

TABLE 3.5

RESULTS OF SEDIMOT-II SIMULATION FOR
HONEY CREEK SEDIMENT TRAP

VARIABLE	UNITS	VALUE
Drainage Area	sq miles	40.0
Inflow Peak	cfs	789.0
Peak Stage	ft	648.65
Total Inflow	acre-ft	585.4
Total Sediment Yield	tons	1,464.4
Trap Efficiency	percent	52.0
Storage Capacity at EL. 648.0	acre-ft	111.7
Storage Capacity at EL. 644.0	acre-ft	48.2
Storage Capacity at EL. 642.0	acre-ft	20.9

On the average, Honey Creek basin is estimated to receive about 1.74 acre-ft or 3,252 tons of sediment per year. The occurrence of two (2) storms of the type analyzed in Table 3.5 in a year may constitute about 90.0 percent of the total annual sediment yield. Assuming a trap efficiency of 52.0 percent, the basin is likely to trap about 0.90 acre-ft per year. If 4.0 feet of sediment deposition is allowed above the bed of the basin, then maintenance dredging may be required every 50 years. If only 2.0 feet of sediment deposition is allowed, then maintenance dredging may be required every 20 years. The trap efficiency of the basin is likely to reduce with sediment deposition in the basin during the interval between two (2) successive dredging operations.

Using the cross-sections of Figures 3.3 (b) and 3.3 (c), the volume of dredging for this trap is estimated to be 162,000 cubic yards. There is a peninsula (500 feet x 100 feet x 8 feet), between the above mentioned cross-sections with vegetation, which was created by a local resident which may not be environmentally acceptable to disturb. The resultant dredging will be 147,185 cubic yards (162,000-14,815).

The input and output of a typical SEDIMOT-II computer simulation are included in Appendix D.

3.1.4 Sediment Trap on Carnahan Ditch Upstream of Bridge Crossing

Carnahan Ditch is a westward flowing tributary of Lake Shafer and drains an area of about 6.0 square miles (USGS Quadrangle Maps for Monticello North and Idaville, Indiana). A plan of the proposed sediment trap upstream of the bridge crossing is shown in Figure 3.4 (a).

Preliminary dimensions of the sediment trap on this ditch have been estimated by field inspection and review of the USGS topographic map of the area (Monticello North Quadrangle). The proposed sediment trap is about 500.0 feet in length, 100.0 feet in width and 5.0 feet in depth. An approximate cross-section of the basin is shown in Figure 3.4 (b). The available information for this trap does not justify a computerized analysis. The volume of material to be dredged for this basin is estimated to be about 2,600 cubic yards.

Using the average rate of sedimentation computed previously, the watershed of Carnahan Ditch may contribute about 0.26 acre-ft/year. The total capacity of the basin below the normal pool elevation (648.0 ft) is about 3.67 acre-ft. The average annual runoff of streams in the vicinity is about 11.0 inches (USGS 1979). Thus the average annual inflow to the sediment trap may be about 3,520 acre-ft. The ratio of basin capacity to average annual

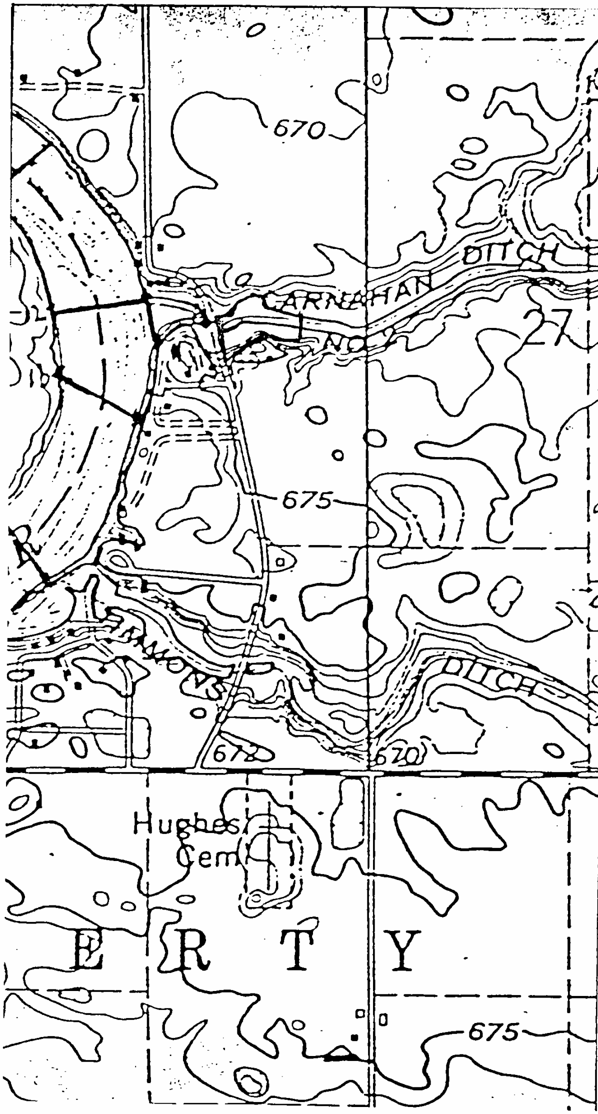

FIGURE 3.4 (a) PLAN OF SEDIMENT TRAP ON CARNAHAN DITCH

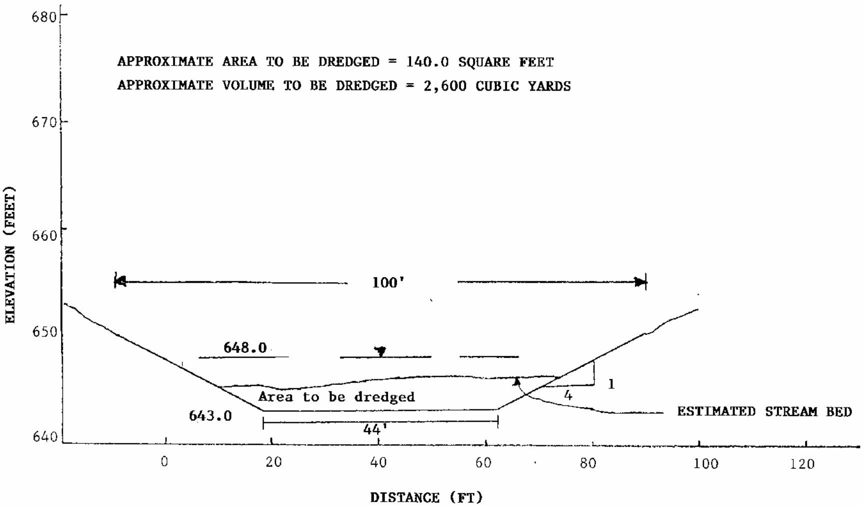

FIGURE 3.4 (b) APPROXIMATE CROSS-SECTION OF SEDIMENT TRAP ON CARNAHAN DITCH

inflow is 0.001. Using Churchill's curve (USBR 1987) the trap efficiency for this basin is estimated to be about 13.0 percent (see Appendix J). Assuming that the sediment trap will be dredged out as soon as 2.0 feet of deposition has occurred, maintenance dredging will be required every 35 years.

This sediment trap is likely to trap approximately 63 tons of sediment per year. The trap efficiency will reduce with sediment deposition in the trap. The US Fish and Wildlife Service indicated that the construction of this sediment trap would disrupt wildlife habitat. Therefore, this sediment trap is not considered feasible. However, a more suitable site might be located further upstream at a more environmentally acceptable area. Such determination is considered beyond the scope of this study.

3.2 Dredging - Locations, Sizes & Estimated Costs

In addition to the sediment traps mentioned in Section 3.1, dredging is necessary in the shallow portions of the lake to maintain a minimum water depth of 5.0 feet ~~within~~ beyond a line 20.0 feet of the shoreline. Water depth of 5.0 feet is selected to keep ice jams from forming and for safe navigation of recreational boats (Strange, 1983). Dredge slopes near the shoreline are to be maintained at 4H:1V.

Dredging is required in Tippecanoe River (at transect #'s 1, 2, 3, 6, 7, 8, 9, 10, 12, 13, 14, 15, 16 and 19), Lake Shafer (at transect #'s 23, 24 and 25), Big Monon Bay (at transect #'s 54, 55, 56, 59, 60, 60-A, 61, 62, 63, 64 and 65), Keans Bay (at transect #36) and Honey Creek (at transect #44). Dredging computations and dredging location map are included in Appendix E.

Dredging computations for the following two (2) locations are not included in Appendix E.

(1) near the northeast corner of Hoagland Bay bridge crossing (250.0 ft. x 200.0 ft. x 3.0 ft = 3402.8 cubic yards) and

(2) area between transect #23 and approximately 300.0 ft. upstream of it (601.5 ft.^{2} x 300.0 ft. = 6683.3 cubic yards).

Dredging required at these two (2) locations has been added to the total computed for Lake Shafer.

Dredging locations within Lake Shafer, its tributaries, and sediment traps; quantity of sediment to be dredged at each location; and estimated costs of dredging are provided in table 3.6.

TABLE 3.6

DREDGING LOCATIONS, QUANTITY AT EACH LOCATION AND ESTIMATED COSTS

LOCATION	QUANTITY ACRE-FT.	QUANTITY CUBIC YARDS	ESTIMATED COST[b] IN DOLLARS
Tippecanoe River	182.5	294,433	883,299
Lake Shafer	42.8	69,051	207,153
Big Monon Bay	102.0	164,560	493,680
Keans Bay	4.1	6,615	19,845
Honey Creek	7.1	11,455	34,365
Hoagland Bay[a]	64.5	104,000	312,000
Honey Creek[a]	100.4	162,000	486,000
TOTAL	503.4	812,114	2,436,343

[a] Sediment Trap

[b] Based on Hydraulic dredging cost at \$3.00 per cubic yard

The two (2) basic types of dredging methods available are hydraulic dredging and mechanical dredging. In mechanical dredging the discharge must be along side the place of excavation, or when the spoil cannot be placed along side, scows or barges must be used to carry it away. In hydraulic dredging the centrifugal pump discharges either into the hold of the dredge itself, into barges along side or ashore (Huston, 1970). Since placing discharge along side or carrying it in scows or barges is not feasible, mechanical dredging is not preferred for Lake Shafer. Hence, hydraulic dredging with a main line hose of 8.0 inches or 10.0 inches (internal diameter) is recommended for Lake Shafer and its tributaries. Brief description on dredging methods is included in Appendix G.

Based on the available information from different dredging contractors through telephone conversations and fee schedules, the cost for hydraulic dredging ranges from $1.50 to $3.00 per cubic yard. This cost includes transporting the dredged material up to 3/4 mile. A list of dredging contractors is included in Appendix E. K & S Testing and Engineering, Inc. would be pleased to monitor and manage dredging operations, and provide management services.

The dredging costs shown in Table 3.6 do not include the cost of temporary storage, dewatering, and final disposal. A preliminary estimate of the costs for these items is included in Table 3.7.

TABLE 3.7

ESTIMATED COST FOR DRAINAGE AND DEWATERING

ITEM	UNIT	QUANTITY	RATE ($)	COST ($)
Temporary acquisition of land	acres	170	200.00	4,000.00
Land preparation (grading)	acres	170	lump sum	5,000.00
Drainage	lump sum	lump sum	5,000.00	5,000.00
Chemical Testing of Sediments and Water[a]	lump sum	lump sum	0.00	0.00
Filtration Fence	lump sum	lump sum	5,000.00	5,000.00
Pumping of Drained Water (as required)	month	12	8,000.00	96,000.00
	TOTAL			$145,000.00

[a]Already completed: See Appendix H

The actual location and temporary acquisition of land to be used for drainage and dewatering of dredged material will have to be finalized during subsequent phases of the project. The mode, locations and actual cost for disposal of the dredged material will also have to be determined during subsequent phases.

The discharge of drainage water from the dredged material back to the Tippecanoe River or its tributaries will require a discharge permit from Indiana Department of Environmental Management, Indiana Department of Natural Resources, or EPA.

To conform to the recommendations of US Fish and Wildlife Service, only hydraulic dredging should be used and extensive or prolonged drawdowns of the lake should be avoided. Dredging should be limited to areas necessary to provide adequate passage for boats, shallow areas along the shoreline and areas necessary for boat access to existing facilities. Dredging of vegetated shallow areas should be avoided. Also, dredging in the main channel of the Tippecanoe River should be considered only if it is determined that such work will not adversely impact any significant benthic organisms such as an endangered species of mussel.

3.3 MAINTENANCE REQUIREMENTS

As stated in Section 3.1, there are four (4) potential sites for the construction of sediment traps. Estimated relative contributions of the watersheds upstream of these traps to sedimentation of Lake Shafer are indicated in Table 3.8.

The proposed sediment traps will control sedimentation from 6.4 percent of the total drainage area upstream of Lake Shafer. Sediment yield from about 6.5 percent of the total drainage area is controlled by natural lakes in the upper catchment (Table 2.2). Sediment yield from the remaining 87.1 percent of the drainage area will continue reaching Lake Shafer. Therefore, sediment traps alone may not provide adequate sediment control. They should be supplemented by maintenance dredging. However, construction and periodic clearance of sediment traps at the mouths of tributaries entering Lake Shafer will result in great convenience to local residents in maneuvering their boats in and out of their ramps and may enhance public acceptance of the project.

TABLE 3.8

ESTIMATED SEDIMENT YIELDS OF WATERSHEDS UPSTREAM OF PROPOSED SEDIMENT TRAPS

SEDIMENT TRAP	DRAINAGE AREA (SQ. MILES)	PERCENT OF TOTAL DRAINAGE AREA[a]	STORAGE CAPACITY (ACRE-FT)	ESTIMATED SEDIMENT CONTRIBUTION (ACRE-FT/YEAR)	TRAP EFFICIENCY (PERCENT)	ESTIMATED YEARLY ENTRAPMENT (ACRE-FT/YEAR)	PERCENT OF TOTAL SEDIMENT YIELD TRAPPED BY BASIN[b]
Hoagland Bay	70.0	4.0	68.6	3.0	27.0	0.81	1.1
Honey Creek	40.0	2.3	111.7	1.74	52.0	0.90	1.2
Carnahan[c] Ditch	6.0	0.3	3.67	0.26	13.0	0.03	0.04
TOTAL[d]	110.0	6.4	180.3	4.74		1.71	2.3

[a] Total Drainage Area Above Lake Shafer = 1,732 square miles

[b] Estimated Total Sediment Yield = 75.39 acre-ft/year

[c] Site Not Found Suitable Because of Potential Environmental Impacts

[d] Considering Sediment Traps Only on Hoagland Bay and Honey Creek

A review of recreational boating activities on the lake suggests that the sedimentation problem has become noticeably acute since 1983. Thus the lake is expected to provide reasonably satisfactory recreational boating if its storage capacity is restored to the 1983 level. Assuming an average sedimentation rate of 217.0 acre-ft/year, this would require maintenance dredging of 3255.0 acre-ft from the lake if no sediment traps are provided and 3181.17 acre-ft if the sediment traps perform as designed, at an interval of every fifteen years. Initial dredging of the sediment traps will be required as indicated in Section 3.1.

4.0 PROPOSED SEDIMENT CONTROL PLAN

4.1 Plan Description

A comprehensive sediment control plan to maintain Lake Shafer in a reasonably satisfactory condition from the standpoint of recreational boating fishing, and aesthetics will include the following structural and non-structural actions:

(a) Structural Actions

Construction of sediment traps on Hoagland Bay and Honey Creek as well as consideration of sediment traps or basins in the upper reaches of Big Monon Ditch, Carnahan Ditch, Big Monon Creek and Keans Ditch.

Dredging of shallow portions of the lake so as to maintain a minimum water depth of 5.0 feet within 20.0 feet of the shoreline. This water depth is required to provide sufficient water depth for maneuvering of recreational boats and to minimize the potential of ice-jam formation and breaking with resultant sediment sluicing (Strange, 1983).

Rock, gravel or wood armoring on unprotected portions of the lake shore to minimize potential of wind and boat-generated wave erosion. However, preference should be given to the use of bio-engineered shore erosion protection systems as well as areas of bank erosion along the upper reaches of Lake Shafer's tributaries.

Gully erosion control preferably using bio-engineered erosion control measures and by construction of grade control structures and/or rock armoring as the second best option.

Construction of submerged weir across the Tippecanoe River approximately 2,100 feet upstream of the mouth of Big Monon Ditch, immediately downstream of a nearly right-angle turn in the stream course. Because of abrupt change in the stream course, an appreciable portion of the bedload and suspended load of the stream is likely to be trapped behind this weir. The technical and environmental feasibility and effectiveness of a submerged weir at this location should be studied in detail as a part of the basin-wide erosion and sediment transport study. The construction of such a structure across the Tippecanoe River will require permits from the US Army Corps of Engineers, other federal and state agencies, and a comprehensive environmental impact assessment.

A diverse mussel community is reported to be present in the Tippecanoe River main channel and Lake Shafer. The aforementioned structural measures should be implemented so as to have minimal impact on the mussel community. All wetland areas must be avoided. Preference should be given to bio-engineered methods of erosion control, wherever feasible, e.g., Willow-Post method, use of wide geotextile meshes with gaps filled by vegetated soils, etc.

(b) Non-structural Actions

Promotion of soil conservation and best management practices (BMP's) of cultivation in the upper watershed based on a basin-wide soil erosion and sediment transport study.

Survey of sedimentation in lakes in the upper watershed, assessment of the reduction in their trap efficiencies over time, and development of sediment removal plans for these lakes, if required. Activities on these lakes are beyond the jurisdiction of Monticello Chamber of Commerce and SFLECC. However, these activities do constitute an integral part of a comprehensive plan for reduction of sedimentation in Lake Shafer.

Modification of water release patterns from the lake so that a good portion of sediment-laden flood water is discharged through turbine bypass rather than by overtopping, as far as possible. If feasible, this plan will discharge portions of the large sediment load transported by flood waters downstream of the lake. This option may not be viable because of potential impacts on mussel population in Lake Freeman.

Vegetation of denuded surfaces and gullies in the watershed.

Reclamation of mine disturbed lands in the watershed.

Erosion control on construction disturbed lands in the watershed by requiring the construction of temporary sediment basins.

Repetition of lake surveys every fifteen (15) years, preferably using the same transects as used in this study (1993 survey) and assessment of the effectiveness of adopted sediment control measures.

A majority of the above-mentioned non-structural actions involve basin-wide planning. These activities should be incorporated in a state-sponsored comprehensive management plan to reduce sedimentation in Lake Shafer. The Monticello Chamber of Commerce and SFLECC should request the State of Indiana or the Federal Government to take appropriate actions to implement these measures.

4.2 Sediment Removal Requirements

Based on review of historic recreational uses of the reservoir, previous reports, discussions with representatives of the client, and professional judgement, the minimum acceptable depth of water is recommended to be 5.0 feet. The estimated volumes of sediment removal and costs for four (4) maintenance intervals are given in Table 4.1. These estimates are based on the assumption that the entire volume of sediment expected to reach Lake Shafer has to be removed. As explained later, the actual quantities of dredging may be somewhat lower.

TABLE 4.1

ESTIMATED VOLUMES OF SEDIMENT REMOVAL AND COSTS FOR FOUR (4) MAINTENANCE INTERVALS

MAINTENANCE INTERVAL YEARS	LAKE DREDGING ACRE-FT	SEDIMENT TRAP DREDGING ACRE-FT	TOTAL DREDGING ACRE-FT	DRAINAGE & DEWATERING COSTS	ESTIMATED COST DOLLARS[a]
5	371.0	0.0	371.0	95,768	1,891,408
10	742.0	0.0	742.0	191,535	3,782,815
15	1113.0	0.0	1113.0	287,302	5,674,222
20	1484.0	34.2	1518.2	391,898	7,574,458

[a] Estimated costs include drainage and dewatering cost, and transporting spoil material up to 3/4 mile using hydraulic dredging at $3.00 per cubic yard

As shown in Table 4.1 the estimated costs are increasing in proportion with the number of years. In addition to these direct costs, there will be indirect costs like project management, surveying, mobilization and demobilization of dredging equipment and its accessories each time dredging operations are conducted. However, considering the total cost involved in dredging operations, these additional costs (about $100,000.00) will constitute a small portion of the total capital cost.

If the maintenance interval is too short (less than five (5) years) the overhead costs become significant. Frequent dredging (shorter maintenance schedule) affects recreational uses of the lake. More over, frequent dredging induces agitation of sediments which may adversely impact the mussel population and hydroelectric power plant operation at Norway Dam. If the maintenance interval is too long, maintaining a minimum depth of 5.0 feet creates a problem for the navigation of watercraft because of excessive accumulation of sediments.

Generalized sediment distribution design curves for reservoirs (USBR, 1987) indicate that in a 30.0 feet deep lake, at least 50.0 percent of the anticipated sediment deposition is expected to take place in portions of the lake where the water depth exceeds 5.0 feet. This portion of sediment deposition is not likely to impede recreational boating and may not have to be dredged out.

Assuming uniform deposition along the reservoir bottom and a lake area of about 1120.0 acres, estimated average depths of deposition are 4, 8, 12 and 16 inches after 5, 10, 15 and 20 years, respectively, after initial dredging operations. With initial dredging accomplished to attain a minimum water depth of 5 feet, it will take 15 to 20 years of sedimentation to have any significant impact on recreational boating. However, layers of these sediments can increase flood stages and flow velocities as well as adversely impact the lake's fisheries.

Based on the above mentioned economic and engineering considerations a maintenance interval of 15 years is recommended. This interval seems reasonable to maintain the minimum acceptable depth of 5.0 feet throughout the lake and its tributaries. After a period of 15 years, lake surveys should be conducted to ascertain the actual depths and locations of deposition and to determine the quantities of maintenance dredging.

4.3 Disposal Plan

The selection of a disposal plan is dependent on the nature of the dredged material, potential environmental impacts of the disposal of dredged material, nature and degree of contamination, dredging equipment, project size, site specific conditions, technical feasibility, economics, and other socio-economic factors.

A typical disposal plan for material dredged out of Lake Shafer would include the following steps:

1. Assessment of contamination potential during drainage and dewatering of dredged material
2. Selection of potential disposal alternatives
3. Selection of specific disposal site or sites
4. Identify potential socio-economic problems associated with the selected alternative
5. Analyses, investigations, and actions to resolve the problems
6. Selecting an implementation strategy
7. Identifying options to minimize adverse impacts and costs
8. Examining design considerations to evaluate technical and economic feasibility
9. Choosing appropriate disposal and control measures and technologies
10. Evaluation of environmental impacts associated with the disposal plan
11. Procurement of all necessary permits for the implementation of the selected disposal plan

Review of previously conducted chemical test results indicated that the sediments are not expected to contain contaminants in significant concentrations (National Environmental Testing, Inc., 1991). However, it is recommended that these findings be confirmed before finalizing a disposal plan particularly with respect to the presence of agricultural pesticides and other toxic materials in the lake sediments.

4.3.1 Disposal Alternatives

Based on the chemical results for the sediments supplied to us, disposal alternatives available are open water, confined and productive uses, which include peripheral embankments for marsh or wetland development and other beneficial uses (Montgomery & Leach, 1984). Openwater disposal will involve drawing down the lake and distributing the sediment into deeper portions (or areas) of the lake by conventional methods of excavation and pushing. Upland disposal will involve the use of open pits, landfills, etc. Of the above mentioned alternatives, confined disposal combined with productive use of dredged material is suitable for Lake Shafer. Brief description on open water disposal and confined disposal is included in Appendix G.

Based on the chemical quality of the dredged material, it may be possible to sell it as clean backfill material. Following are some of the beneficial uses of dredged material which may be used for negotiations with potential recipients.

1. Dredged material can be used as topsoil to provide vegetative cover erosion-prone land surfaces in the site vicinity.

2. Dredged material can be used to fill open mine pits, borrow areas and other depressions.

3. Dredged material may be suitable for backfill and embankment fill after appropriate testing and dewatering.

4. Dewatered dredged material can be used as a substitute for conventional landfill cover material.

4.3.2 Selection of Disposal Site

Disposal site selection includes environmental review, analysis of engineering factors, economics, best use analysis and land acquisition options. The criteria for disposal site selection are given below.

1. Environmentally sensitive areas should be avoided. This may include wetlands, wildlife refuge areas, existing ponds, swales, and stream channels.

2. Evaluation of sites with respect to permit requirements, e.g., city and county regulations and U.S. Army Corps of Engineers, permit for land disposal of non-hazardous materials and state regulations for dust control, etc.

3. Engineering considerations (e.g. pumping distance, dredged material characteristics, capacity of disposal site, etc.)

4. Particular local concerns (e.g. feasibility of land acquisition, aesthetics, best use analysis, public acceptance etc.).

5. Long-term versus short-term disposal needs and problems. A long-term disposal area may require permanent land acquisition and installation of permanent facilities for drainage, storage, and removal of dredged material.

6. Specific protection requirements for disposal at the site (e.g. disposal in erosion-prone areas will require erosion control measures. Disposal in pits, quarries, borrow areas, etc. may require compaction and top cover).

7. Accessibility for preparation use, and maintenance of site.

Based on our reconnaissance, map study and communications with local residents, the following locations are identified for possible sediment disposal.

<u>Farm land near Lowe's Bridge</u>

About 160 acres of agricultural land located to the northeast of Lowe's Bridge is a potential site for disposal of spoil material. During telephone conversation, Mr. Ron Stanley, owner of land, expressed his interest to accept the dredged material at his site.

<u>Stone Quarries of a Trucking Company in Monon</u>

Stone Quarries in Monon are also a suitable site for dredged material disposal. But currently they are not available for disposal.

<u>Abandoned Sand Pits Located near Monon</u>

Abandoned sand pits located approximately 8.0 miles from Big Monon Bay are also suitable for dredged material disposal. Exact ownership of these sand pits was unable to be determined.

Of the above identified disposal sites the farm land located northwest of Lowe's Bridge appears to be a suitable disposal site for major portion of the dredged material from Lake Shafer and its tributaries. The site is very close to the lake, thus reducing the pumping distance of the spoil material. From engineering and economical point of view, this is a suitable disposal site. However, local residents should be contacted to determine the cultural and environmental sensitivity of the area.

Telephone conversation with Mr. Bob Coates (SFLECC) revealed the availability of additional disposal areas. Mr. Bruce Clear of IDNR, Monticello, Indiana was contacted for further information on these sites. Additional disposal areas identified during the site visit (on October 26, 1993) with Mr. Bruce Clear are given below:

> Filling up of irregular topography near (approx. 1000 ft. south of) Hoagland Bay. Mr. Don Lane, owner of the property, is interested in accepting the sediment.
>
> NIPSCO property located southwest of bridge crossing on Little Monon
>
> NIPSCO property located approximately ½ mile to the northwest of the bridge crossing on Little Monon

A map showing potential disposal site locations is included in Appendix E. The identified disposal sites need further evaluation regarding their capacity community acceptance, environmental sensitivity, feasibility of land acquisition, engineering considerations, permit requirements, etc.

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4.4 Estimated Cost

Based on the sediment removal methods and disposal sites identified the following alternatives are considered as viable:

1. Disposal at farm land (near Lowe's Bridge)
   (a) conventional (dry) excavation
   (b) hydraulic dredging

2. Disposal at sand pits (near Monon)
   (a) conventional (dry) excavation
   (b) hydraulic dredging

3. Disposal into deeper portions of lake using conventional (dry) excavation

Cost estimates for the removal and disposal of sediments using the above mentioned alternatives are shown in Table 4.2. The total capital cost for the preferred alternative is estimated to be $2,051,108.00. This involves hydraulic dredging with disposal on the farm land northeast of Lowe's Bridge.

The cost for drainage and dewatering of the hydraulically dredged material are included in this estimate.

TABLE 4.2

COST ESTIMATES FOR REMOVAL AND DISPOSAL OF SEDIMENTS
(QUANTITIES OF DREDGED MATERIAL ARE SHOWN IN TABLE 3.7)

DISPOSAL SITE	DISTANCE (MILES)	REMOVAL COST (DOLLARS)	TRANSPORTATION COST (DOLLARS)	DRAINAGE & DEWATERING COSTS (DOLLARS)	TOTAL COST (DOLLARS)
(1) Farm land					
(a) conventional dry excavation	2.5	2,842,399	1,218,171	0	4,060,570
(b) hydraulic dredging	2.5	2,436,343[a]	281,880	145,000	2,863,223
(2) Sand Pits					
(a) conventional dry excavation	12.0	2,842,399	5,847,221	0	8,689,620
(b) hydraulic dredging	12.0	1,624,228	1,395,144	145,000	3,164,372
(3) Lake-using conventional dry excavation	500 ft.	3,248,456	0	0	3,248,456

[a] See Table 3.6

The estimated costs are based on the information obtained through telephone conversations with contractors, available fee-schedules, and professional judgement. Following are the information used in computing the estimated costs:

1. Assumed average distances of farm land (near Lowe's Bridge) and sand pits (near Monon) from sediment removal locations are 2.5 miles and 12.0 miles, respectively.

2. Assumed length of dredging time is 6.0 months using one (1) hydraulic dredge having a main line hose of 8.0 inches in diameter.

3. Cost of sediment removal by hydraulic dredging is $3.00 per cubic yard.

4. Rental rate of booster pump is $4,500.00 per month with an additional cost of $10.00 per hour.

5. Rental rate for main line hose of 8.0 inches is $0.90 per foot per month.

6. Cost of sediment removal using conventional (dry) excavation is $3.50 per cubic yard.

7. Rate of hauling sediment to the disposal site is $0.60 per mile per cubic yard.

8. Cost for conventional (dry) excavation and spreading in deeper portions of Lake is $4.00 per cubic yard.

From Table 4.2 it can be observed that the least expensive alternative would be disposal of sediment at the farm land using hydraulic dredging. Hence, this alternative can be considered for the removal and disposal of the sediment from Lake Shafer and its tributaries.

Some of the action items to be considered before dredging and disposal of sediment include the following:

1. Make a site visit, and contact the owner and the neighbors in the vicinity of the disposal site.

2. Discuss financial and legal arrangements.

3. Develop a schedule of dredging and disposal plan.

4. Assess the need for disposal restrictions (whether wet material is accepted).

5. Examine design considerations to evaluate technical and economic feasibility.

6. Evaluate contamination potential of sediment.

7. Submit the dredging and disposal plan to IDNR for environmental review.

8. Identify required regulatory permits, prepare applications, and obtain all necessary permits.

9. Develop an implementation plan including selection of dredging contractor, drainage plan, erosion protection, schedule of dredging operations, etc.

10. Notify NIPSCO about potential agitation of sediments in the lake induced by dredging.

11. Obtain appropriate environmental permits. Costs associated with permitting and any possible mitigation are not included in this study.

5.0 CONCLUSIONS

5.1 Planning Options

The planning options for sediment control in Lake Shafer include the following:

Lake dredging with or without the construction of sediment traps

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Lake dredging by drawing down (ie., reasonably dry excavation) or by conventional underwater dredging methods

Disposal of dredged material in existing mine pits, farm lands, or spoil piles

Procurement of IDNR's environmental review and necessary environmental permits

Investigation of alternative sources of funding (ie., through government subsidies, grants or aid; through bonds; through user taxes; or implementation in phases using available resources).

Limited quantitive and qualitative information is available about the sediment load transported by the streams on which sediment traps are proposed. This information indicates that these streams may transport proportionately larger quantities of sediment loads. Therefore, it is advisable to construct the proposed sediment traps and supplement them by lake dredging so as to attain the storage capacity of 1983.

The information presented in Table 4.2 indicates that hydraulic dredging is more economical as compared to excavation during periods of lake draw down or sub-aqueous disposal of excavated material by pushing it into deeper portions of the lake.

To minimize the cost of hauling, the disposal sites should be as close to the lake as possible. Selection of a suitable location or locations will involve public relations, political, legal, institutional and financial issues requiring negotiations between different parties. Resolution of these issues is beyond the scope of this study. Preliminary enquiries indicated that the farm land northeast of Lowe's Bridge is a good example of what may be a suitable disposal site.

If financing of the project becomes difficult, then it may be advisable to undertake the construction of sediment traps and dredging operations in phases. In this way, capital expenditure can be spread over a period of several years.

The environmental impacts of dredging and disposal must be evaluated and IDNR's environmental review must be obtained before finalizing the plan. Also, all necessary permits must be obtained before the implementation of the selected plan.

The estimated capital cost for the preferred dredging and disposal option is $2,863,223. This includes hydraulic dredging with disposal on the farm land northwest of Lowe's Bridge. Cost estimates for permitting or any possible mitigations are not included in this study.

5.2 Study Limitations

During the course of the study (August 1993) the suspended sediment load of the streams was observed to be negligible. Limited field data could be collected during actual flood events when the Tippecanoe River and its tributaries are likely to transport large quantities of sediment load.

Limited information is available about the bedload and suspended sediment loads of the Tippecanoe River and its tributaries. Previous, lake sedimentation surveys were limited to spot measurements of thicknesses of sediment deposits at selected locations exposed during lake draw down. No information is available about surveyed cross-sections of the lake prior to 1993. The accuracy of the estimated incremental rates of sedimentation is dependent on the accuracy of the previous estimates of sedimentation. The error band of the estimated storage capacity of Lake Shafer based on the 1993 surveys is judged to be ±5 percent.

The details of quantities and costs included in this report are at a feasibility level. These details must be refined during the design and construction phases of the study.

Limited field data are available about the quantities of sediments transported during floods of different severities. Suspended sediment samples at selected locations were collected during December, 1994. These samples may not be representative of extreme storms during which significant quantities of sediments are transported. Suspended sediment sampling was completed in December, 1994, after waiting for a reasonably significant storm event. The information used in this study is based on professional judgement and extrapolations of available information on sediment transport characteristics of contributing streams.

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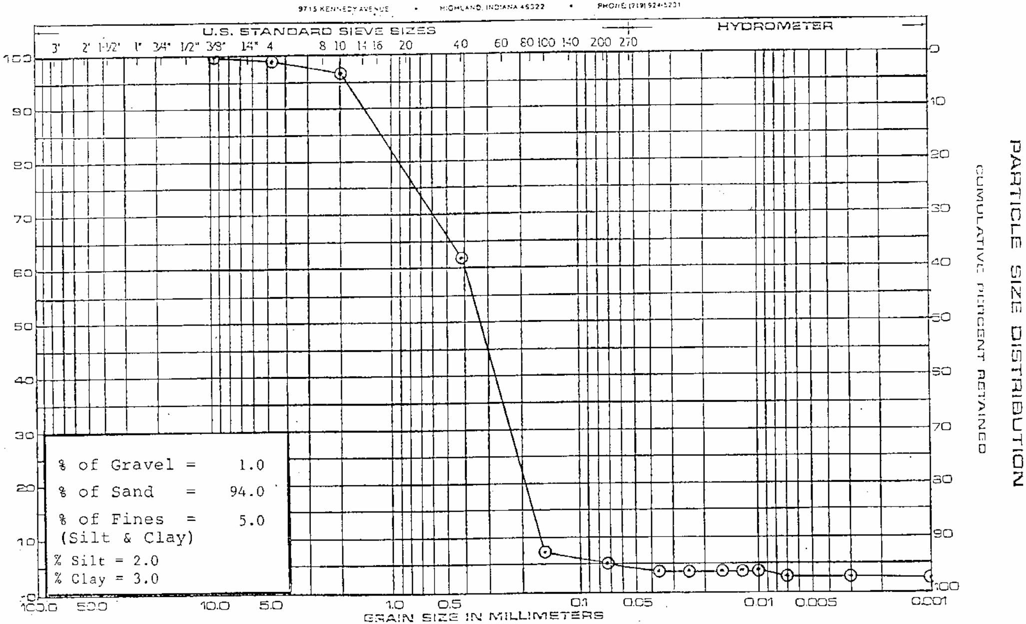
APPENDIX A

PARTICLE SIZE DISTRIBUTION OF BEDLOAD SAMPLES

K&S Testing and Engineering Inc.

9715 KENNEDY AVENUE • HIGHLAND, INDIANA 46322 • PHONE (219) 924-5231



	GRAVEL		SAND			
UNIFIED	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY FINES
ASTM	COARSE	FINE	COARSE	MEDIUM	FINE	SILT AND CLAY FINES
AASHTO	COARSE / MEDIUM	FINE	COARSE		FINE	SILT / CLAY

JOB NAME Lake Shafer Feasibility Study JOB NO. 2465 Location Tippecanoe River SAMPLE Bedload

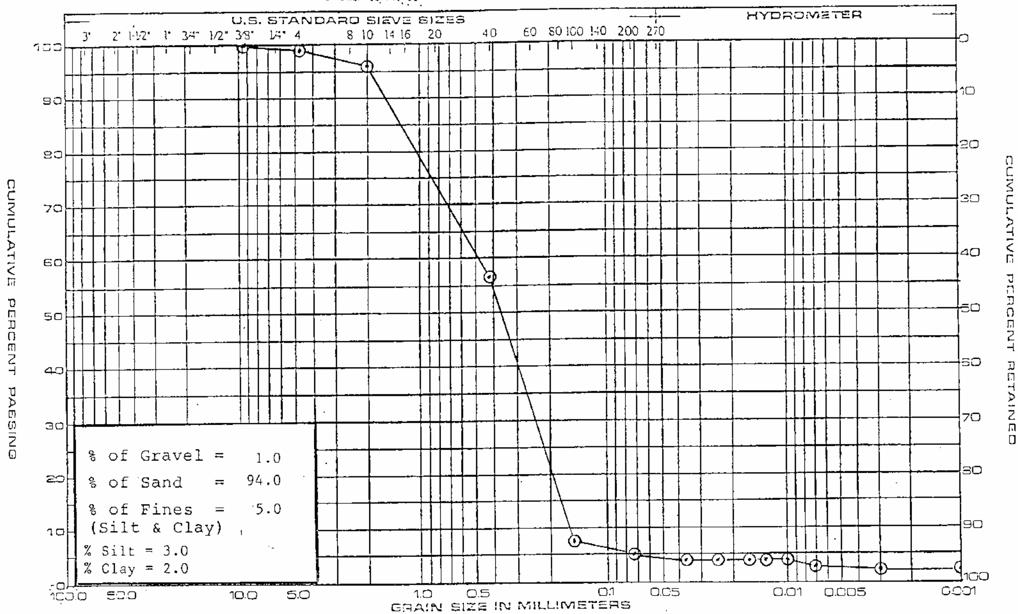
DEPTH 4.0 Feet SOIL DESCRIPTION & CLASSIFICATION Gray fine to coarse Sand, trace fine gravel, shale, silt and clay (SP-SC)

EXHIBIT 1

K&S Testing and Engineering Inc.

9715 KENNEDY AVENUE • HIGHLAND, INDIANA 46322 • PHONE: (219) 924-5231

PARTICLE SIZE DISTRIBUTION



UNIFIED	GRAVEL COARSE	GRAVEL FINE	SAND COARSE	SAND MEDIUM	SAND FINE	SILT AND CLAY FINES	
ASTM	GRAVEL COARSE	GRAVEL FINE	SAND COARSE	SAND MEDIUM	SAND FINE	SILT AND CLAY FINES	
AASHTO	GRAVEL COARSE	GRAVEL MEDIUM	GRAVEL FINE	SAND COARSE	SAND FINE	SILT	CLAY

JOB NAME Lake Shafer Feasibility Study JOB NO. 2465 Location Lake (Near Lowes Bridge) SAMPLE Bedload

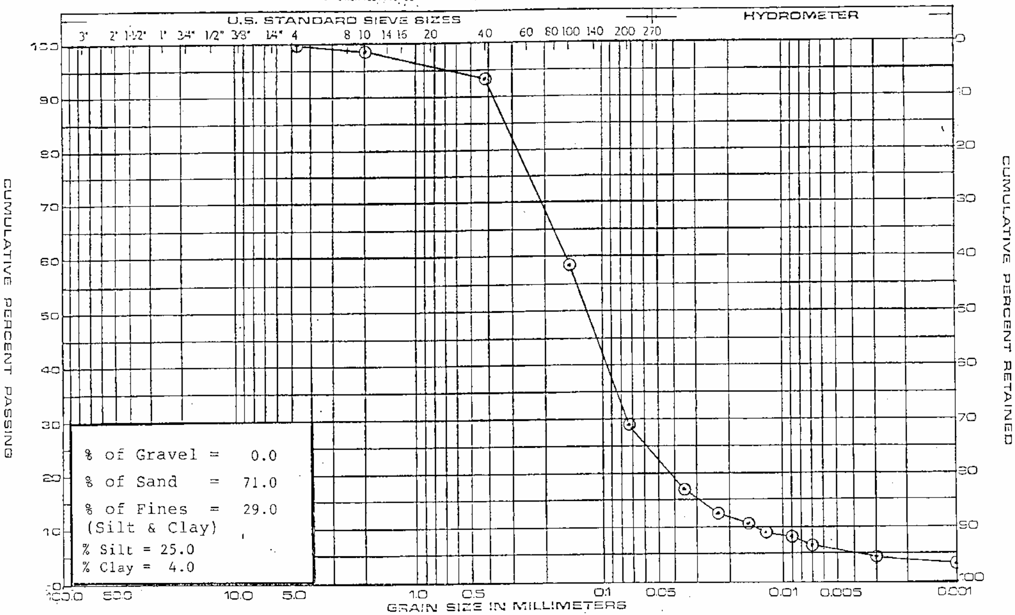
DEPTH 15.0 Feet SOIL DESCRIPTION & CLASSIFICATION Gray fine to coarse Sand, trace fine gravel, shale, silt & clay (SP-SC)

EXHIBIT 2

K&S Testing and Engineering Inc.

9715 KENNEDY AVENUE • HIGHLAND, INDIANA 46322 • PHONE (219) 924-5231

PARTICLE SIZE DISTRIBUTION



UNIFIED	GRAVEL: COARSE	GRAVEL: FINE	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT AND CLAY FINES	
ASTM	GRAVEL: COARSE	GRAVEL: FINE	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT AND CLAY FINES	
AASHTO	GRAVEL: COARSE	GRAVEL: MEDIUM	GRAVEL: FINE	SAND: COARSE	SAND: FINE	SILT	CLAY

JOB NAME Lake Shafer Feasibility Study JOB NO. 2465 Location Hoaglana Bay Mouth SAMPLE Bedload

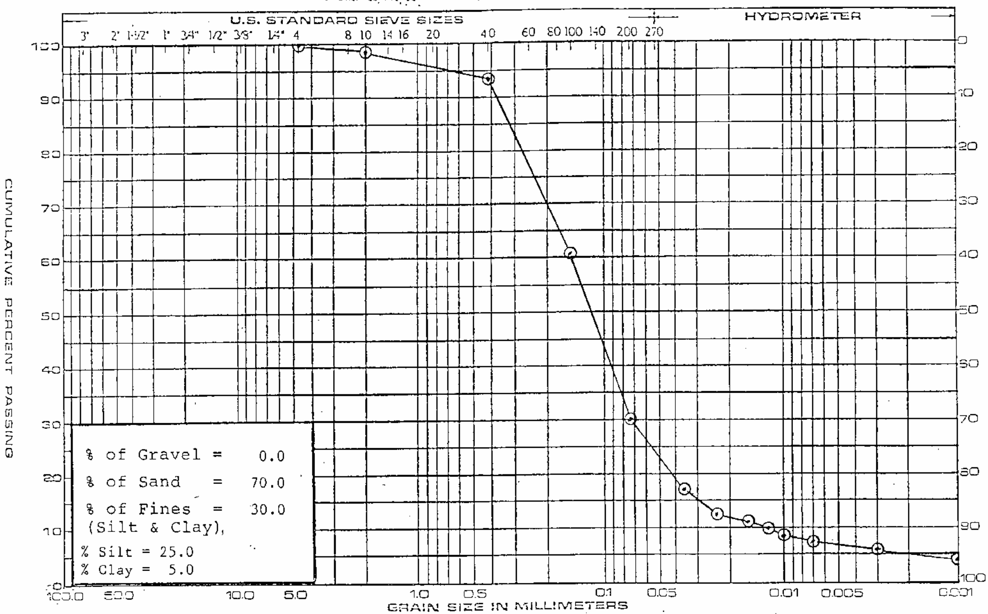
DEPTH 1.5 Feet SOIL DESCRIPTION & CLASSIFICATION Gray fine to coarse Sand, some silt, trace Clay SC-SM)

EXHIBIT 3

K&S Testing and Engineering Inc.

9715 KENNEDY AVENUE • HIGHLAND, INDIANA 46322 • PHONE (219) 924-5231

PARTICLE SIZE DISTRIBUTION



UNIFIED	GRAVEL: COARSE	GRAVEL: FINE	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT AND CLAY FINES
ASTM	GRAVEL: COARSE	GRAVEL: FINE	SAND: COARSE	SAND: MEDIUM	SAND: FINE	SILT AND CLAY FINES
AASHTO	GRAVEL: COARSE / MEDIUM	GRAVEL: FINE	SAND: COARSE		SAND: FINE	SILT / CLAY

JOB NAME Lake Shafer Feasibility Study JOB NO. 2465 Location Hoaglana Bay Mouth SAMPLE Bedload

DEPTH 2.0 Feet SOIL DESCRIPTION & CLASSIFICATION Gary fine to coarse Sand, some silt, trace clay (SC-SM)

EXHIBIT 4

SPECIFIC GRAVITY OF SOIL SOLIDS (G_s)

Data Sheet

Project Lake Shafer   Job No. 2465

Location of Project Monticello, Indiana   Location Tippecanoe River   Sample No.

Description of Soil Gray fine to coarse Sand, trace shell   Depth of Sample Bedload

Tested By Dr. Ali   Date of Testing 9-15-93

fl. = volumetric flask

Test no.	1			
Vol. of flask at 20°C	250 ml			
Method of air removal[a]	Boiling			
Mass fl. + water + soil = M_{bws}	399.3			
Temperature F	72° F			
Mass fl. + water[b] = M_{bw}	363.07			
Dish no.	L-3			
Mass dish + dry soil	107.4			
Mass of dish	49.20			
Mass of dry soil = M_s	58.20			
$M_w = M_s + M_{bw} - M_{bws}$	21.97			
$\alpha = \rho_T/\rho_{20°C}$	0.9996			
$G_s = \alpha M_s/M_w$	7.65			

[a]Indicate vacuum or aspirator for air removal.

[b]M_{bw} is the mass of the flask filled with water at same temp. ± 1°C as for M_{bws}, or value from calibration curve at T of M_{bws}.

Remarks

Average specific gravity of soil solids (G_s) =

APPENDIX B

CROSS-SECTIONAL DATA AND CONTOUR MAP FOR 1993 SURVEY OF LAKE SHAFER

Aug/93

Survey on Lake Shafer: Cross section data for each transect

transect # — first row distance from shore in ft.; second row depth below water surface in ft.

Lake Shafer- Distance from Eastern shore

transect #										Water Surface elevation
23	0.0	10.0	126.3	242.6	358.9	475.2	591.5	707.8	717.8	648.46
	0.0	4.8	12.5	11.0	8.0	3.0	4.0	1.0	0.0	
24	0.0	10.0	123.5	237.0	350.5	464.0	577.5	691.0	701.0	648.56
	0.0	2.5	14.0	8.0	3.0	5.0	6.0	1.0	0.0	
25	0.0	10.0	142.0	274.0	406.0	538.0	670.0	804.0	814.0	648.45
	0.0	1.0	2.0	4.0	6.0	11.0	10.5	1.0	0.0	
26	0.0	10.0	140.5	271.0	401.5	532.0	662.5	793.0	803.0	648.4
	0.0	2.0	9.5	11.0	11.0	6.0	8.0	1.5	0.0	
27	0.0	10.0	171.7	333.4	495.0	656.8	818.5	980.0	990.0	
	0.0	2.0	10.5	10.0	11.0	9.0	7.0	2.5	0.0	
28	0.0	10.0	196.4	382.8	569.2	755.6	942.0	1128.5	1138.5	648.65
	0.0	1.5	7.5	10.0	10.5	11.0	10.0	2.0	0.0	
29	0.0	10.0	166.2	322.4	478.6	634.8	791.0	947.0	957.0	648.7
	0.0	3.0	13.0	12.0	14.0	8.0	4.0	2.0	0.0	
30	0.0	10.0	167.1	324.2	481.3	638.4	795.5	952.5	962.5	648.84
	0.0	3.0	7.0	14.5	16.0	15.0	11.0	4.0	0.0	
31	0.0	10.0	258.8	507.6	756.4	1005.2	1254.0	1502.5	1512.5	648.89
	0.0	3.0	7.0	10.0	10.0	15.0	15.0	12.0	0.0	
32	0.0	10.0	154.5	299.0	443.5	588.0	732.5	742.5		649.73
	0.0	5.0	10.5	13.0	16.0	19.0	11.0	0.0		
33	0.0	10.0	319.8	629.6	929.4	1249.5	1259.5			649.23
	0.0	2.0	18.0	17.0	10.0	1.5	0.0			
37	0.0	10.0	236.8	463.6	690.4	917.2	1134.0	1144.0		649.3
	0.0	2.0	14.5	14.5	16.5	19.5	6.5	0.0		
38	0.0	10.0	263.0	516.0	769.0	1022.0	1275.0	1530.0	1540.0	649.38
	0.0	2.0	5.0	9.0	12.5	16.0	21.0	5.0	0.0	

39	0.0	10.0	280.0	550.0	820.0	1090.0	1100.0			649.41
	0.0	2.0	21.5	20.0	20.0	2.5	0.0			
40	0.0	10.0	223.8	437.6	651.4	865.2	1079.0	1089.0		649.45
	0.0	3.5	6.0	21.0	17.0	13.0	7.0	0.0		
41	0.0	10.0	182.7	355.4	528.1	700.8	873.5	1046.0	1056.0	648.96
	0.0	2.0	5.0	18.0	28.0	28.0	15.0	3.0	0.0	
45	0.0	10.0	227.8	445.6	663.4	881.0	891.0			649.55
	0.0	2.0	8.0	27.0	23.0	1.5	0.0			
46	0.0	10.0	267.8	525.6	783.4	1041.2	1299.0	1309.0		649.55
	0.0	2.0	12.0	17.5	22.0	25.0	20.0	0.0		
47	0.0	10.0	187.5	365.0	542.5	720.0	897.5	907.5		649.64
	0.0	2.5	17.5	21.0	26.0	26.0	5.0	0.0		

Tippicanoe River- Distance from Eastern shore

1	0.0	10.0	82.0	154.0	226.0	236.0		648.51
	0.0	1.5	2.8	7.0	2.8	0.0		
2	0.0	10.0	96.8	183.7	270.5	280.5		
	0.0	1.5	7.5	7.5	3.1	0.0		
3	0.0	10.0	115.0	220.0	325.0	430.0	440.0	648.29
	0.0	3.0	4.5	3.5	5.0	3.0	0.0	
4	0.0	5.0	55.0	105.0	110.0			648.62
	0.0	2.0	7.0	2.0	0.0			
5	0.0	10.0	117.0	224.0	331.0	341.0		
	0.0	3.5	7.5	8.0	4.5	0.0		
6	0.0	10.0	85.6	161.2	246.9	302.5	312.5	
	0.0	3.5	4.0	8.0	7.5	4.0	0.0	
7	0.0	10.0	90.3	170.6	250.9	331.0	341.0	
	0.0	3.0	5.5	8.0	3.0	2.0	0.0	
8	0.0	10.0	156.3	302.6	448.9	595.0	605.0	648.64
	0.0	5.0	9.8	9.8	5.0	0.8	0.0	
9	0.0	10.0	94.4	178.8	263.2	347.0	357.5	648.44

	0.0	2.5	5.0	9.0	5.0	1.5	0.0		
10	0.0	10.0	105.2	200.4	295.6	390.8	400.8		
	0.0	1.0	2.0	0.5	13.0	12.0	0.0		
12	0.0	10.0	149.0	288.0	427.0	566.0	705.0	715.0	
	0.0	1.5	3.0	5.5	5.5	8.5	4.0	0.0	
13	0.0	10.0	163.1	316.2	469.3	622.5	632.5		
	0.0	7.0	7.0	4.5	0.5	3.5	0.0		
14	0.0	10.0	137.0	264.0	391.0	518.0	528.0		
	0.0	2.0	7.0	3.0	2.5	0.5	0.0		
15	0.0	10.0	158.0	307.6	456.4	595.0	605.0		
	0.0	2.0	8.0	3.0	2.3	2.0	0.0		
16	0.0	10.0	170.0	330.0	490.0	650.0	660.0		
	0.0	4.0	8.0	2.0	10.0	5.0	0.0		
18	0.0	10.0	170.0	330.0	490.0	650.0	660.0		648.25
	0.0	2.0	9.0	5.0	14.5	2.0	0.0		
19	0.0	10.0	149.4	288.8	428.2	567.5	577.5		648.24
	0.0	2.0	5.5	5.5	12.0	4.5	0.0		
20	0.0	10.0	142.5	275.0	407.5	540.0	550.0		648.29
	0.0	5.0	9.0	5.5	10.0	4.0	0.0		
22	0.0	10.0	128.7	247.4	366.1	485.0	495.0		648.35
	0.0	5.0	14.0	18.0	16.0	5.0	0.0		

Honey Creek Bay- Distance from Southern shore

42	0.0	10.0	110.0	210.0	310.0	409.8	419.8
	0.0	3.0	17.0	18.0	17.0	3.0	0.0
43	0.0	10.0	128.8	247.6	366.4	485.0	495.0
	0.0	7.0	12.0	11.5	10.0	3.0	0.0
44	0.0	10.0	225.0	440.0	655.0	870.0	880.0
	0.0	4.0	3.5	6.5	6.5	3.0	0.0

Keans Bay- Distance from Southern shore

34	0.0	10.0	87.5	165.0	242.5	320.0	330.0
	0.0	2.5	8.5	17.0	18.0	8.0	0.0

35	0.0	10.0	149.4	288.8	428.2	567.5	577.5
	0.0	2.5	13.0	12.5	10.5	3.0	0.0
36	0.0	10.0	110.0	210.0	310.0	413.5	423.5
	0.0	1.5	4.5	7.0	6.5	3.0	0.0

Hoglana Bay- Distance from Southern shore

48	0.0	10.0	112.5	215.0	317.5	420.0	430.0
	0.0	4.0	8.0	9.0	8.0	7.0	0.0
66	0.0	10.0	73.8	137.6	201.4	265.0	275.0
	0.0	4.0	4.1	2.0	1.0	0.5	0.0

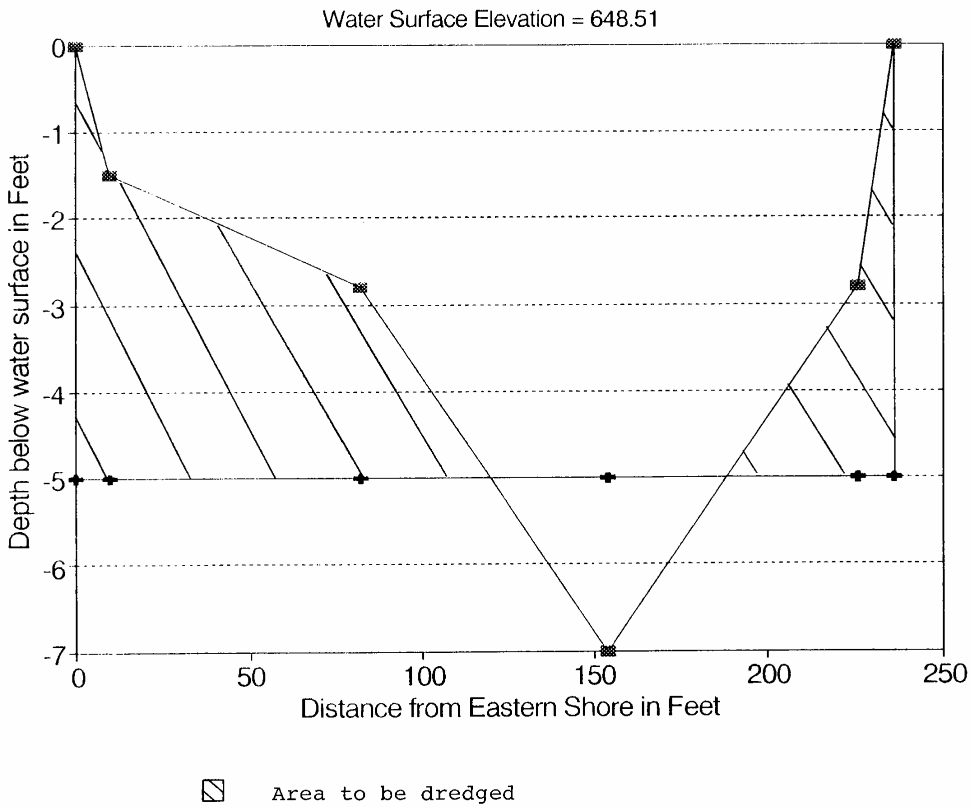
Big Monon Bay (creek)- Distance from Northern Shore

49	0.0	10.0	160.4	310.8	461.2	611.5	621.5			648.57
	0.0	2.0	10.5	19.0	15.0	4.0	0.0			
50	0.0	10.0	128.8	247.6	366.4	485.0	495.0			
	0.0	2.0	7.0	13.0	14.0	8.0	0.0			
51	0.0	10.0	170.0	330.0	490.0	650.0	660.0			
	0.0	2.0	8.5	11.0	13.0	8.5	0.0			
53	0.0	10.0	223.3	436.6	650.0	660.0				648.95
	0.0	14.0	13.0	5.5	2.0	0.0				
54	0.0	10.0	226.7	443.4	660.1	876.8	1093.5	1310.0	1320.0	
	0.0	6.0	10.0	12.0	12.0	12.0	4.0	4.0	0.0	
56	0.0	10.0	94.4	178.8	263.1	347.5	357.5			648.95
	0.0	2.0	6.0	10.0	6.5	1.0	0.0			
59	0.0	10.0	138.4	266.8	395.1	523.5	533.5			
	0.0	1.0	9.0	9.0	7.0	1.0	0.0			
60	0.0	10.0	87.5	165.0	242.5	320.0	330.0			
	0.0	3.0	7.0	7.0	9.0	3.0	0.0			
60A	0.0	10.0	163.1	316.3	469.4	622.5	632.5			
	0.0	2.0	2.5	5.0	6.0	4.0	0.0			
61	0.0	10.0	163.1	316.3	469.4	622.5	632.5			648.96
	0.0	1.0	4.0	2.5	5.0	1.0	0.0			

62	0.0	10.0	105.4	200.8	296.1	391.5	401.5
	0.0	1.0	5.0	6.0	5.0	1.0	0.0
64	0.0	10.0	73.8	137.5	201.3	265.0	275.0
	0.0	2.5	5.0	5.0	6.0	5.0	0 0
65	0.0	10.0	80.0	150.0	220.0	290.0	300.0
	0.0	2.5	3.1	6.5	3.5	2.0	0.0
63	0.0	10.0	105.0	200.0	295.0	390.0	400.0
	0.0	0.5	4.0	4.0	4.0	0.5	0.0

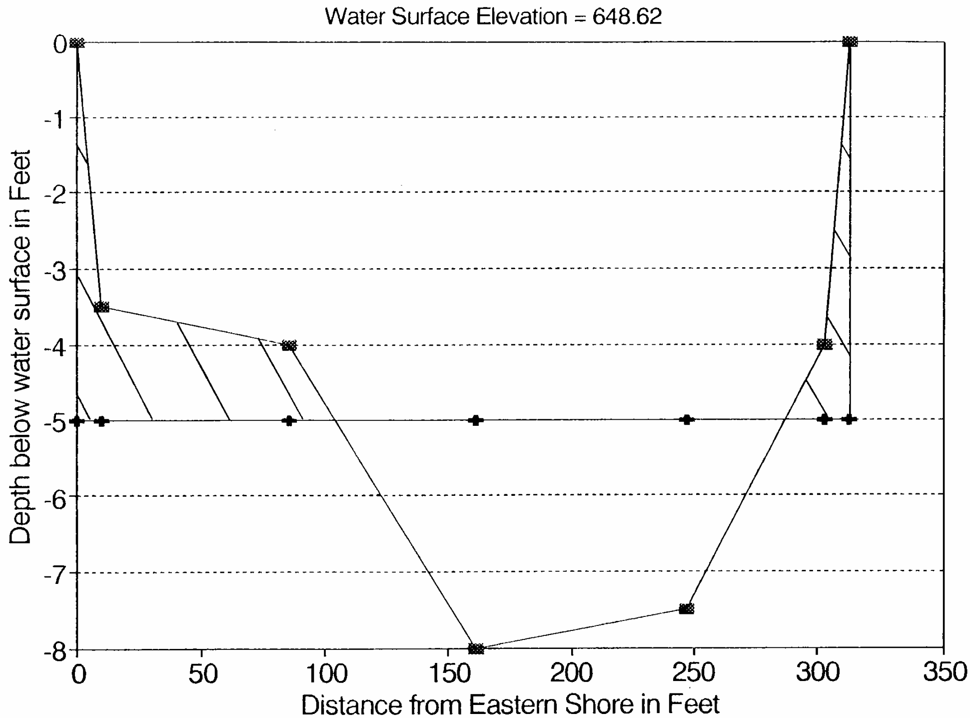
CROSS SECTION OF TRANSECT NO. 1

44253.0 ft. Upstream along Tippecanoe River from Norway Dam



CROSS SECTION OF TRANSECT NO. 6

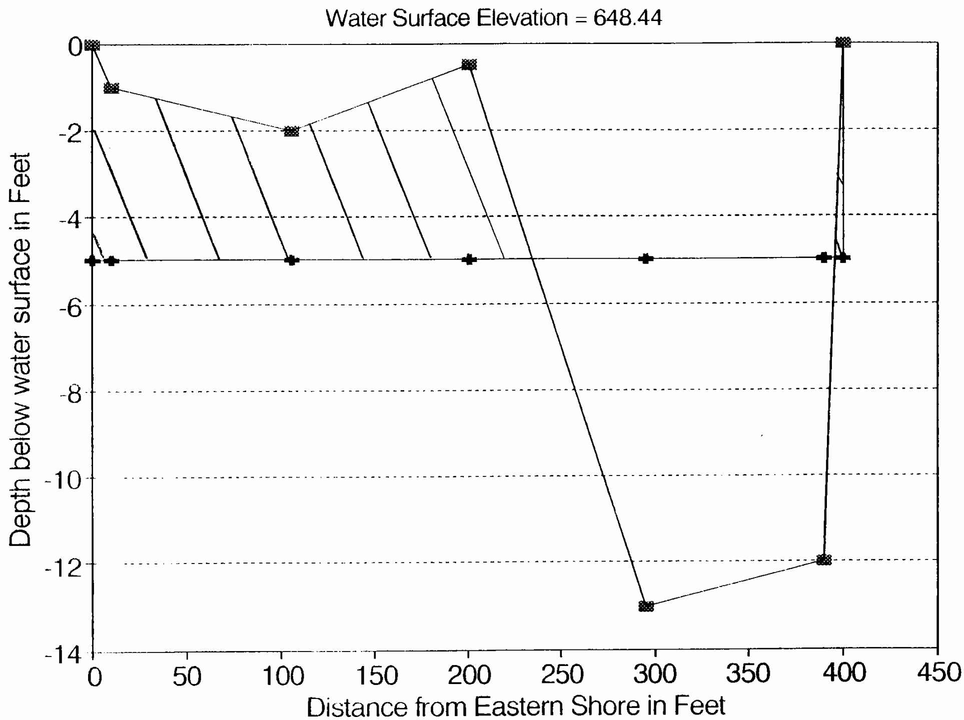
40997.0 ft. upstream along Tippecanoe River from Norway Dam



Area to be dredged

CROSS SECTION OF TRANSECT NO. 10

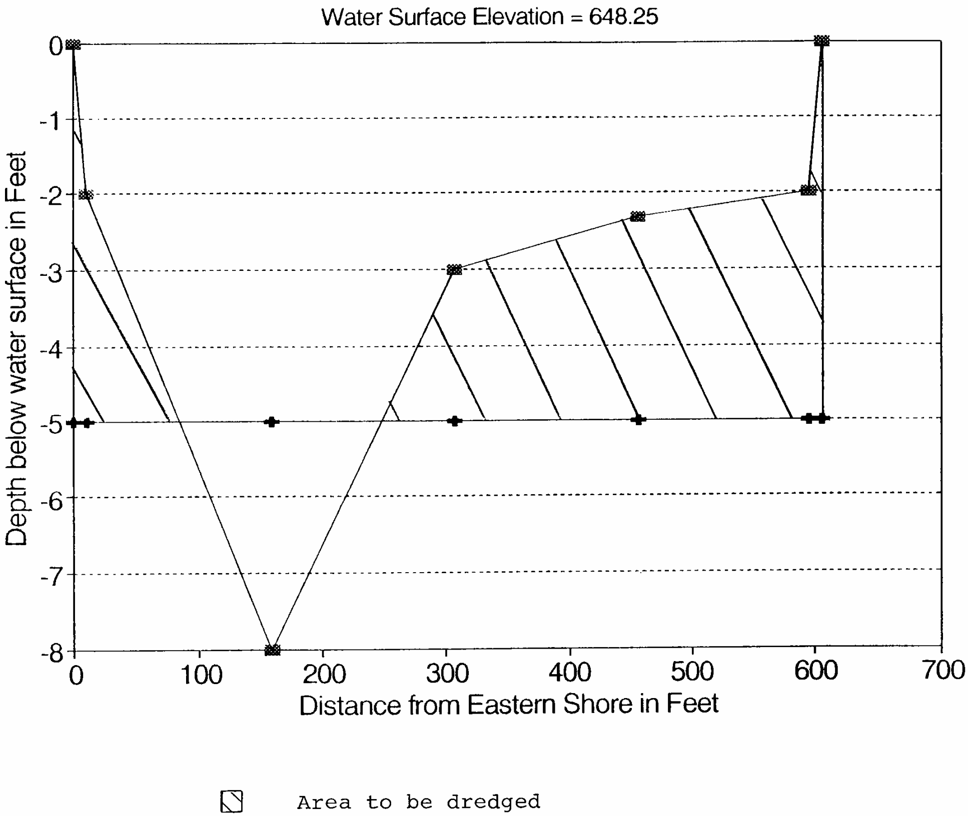
35678.5 ft. upstream along Tippecanoe River from Norway Dam



Area to be dredged

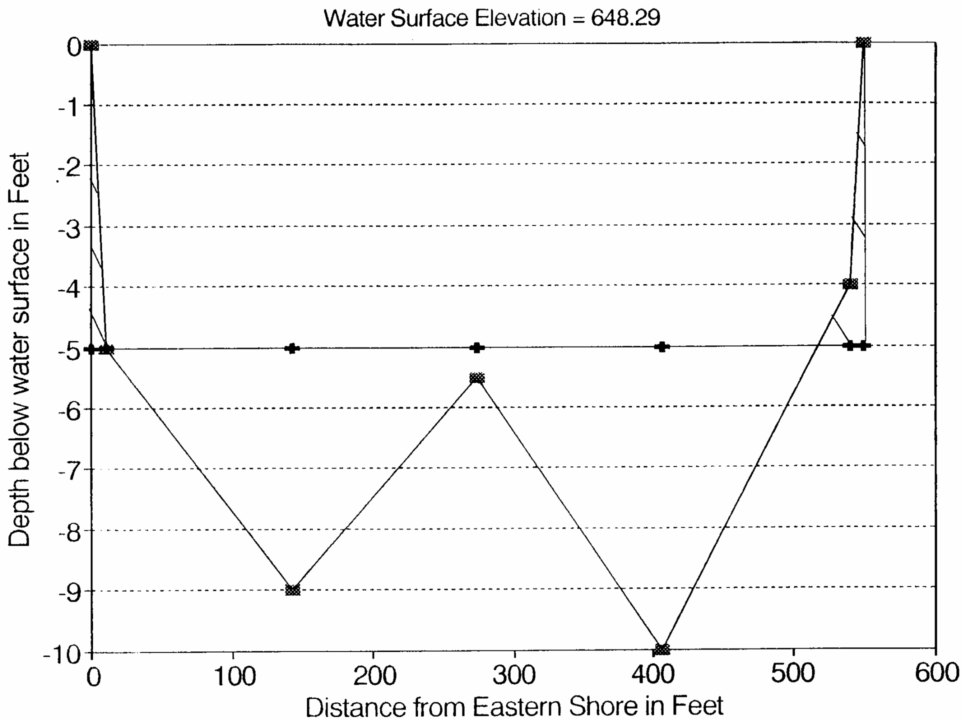
CROSS SECTION OF TRANSECT NO. 15

31790.0 ft. upstream along Tippecanoe River from Norway Dam



CROSS SECTION OF TRANSECT NO. 20

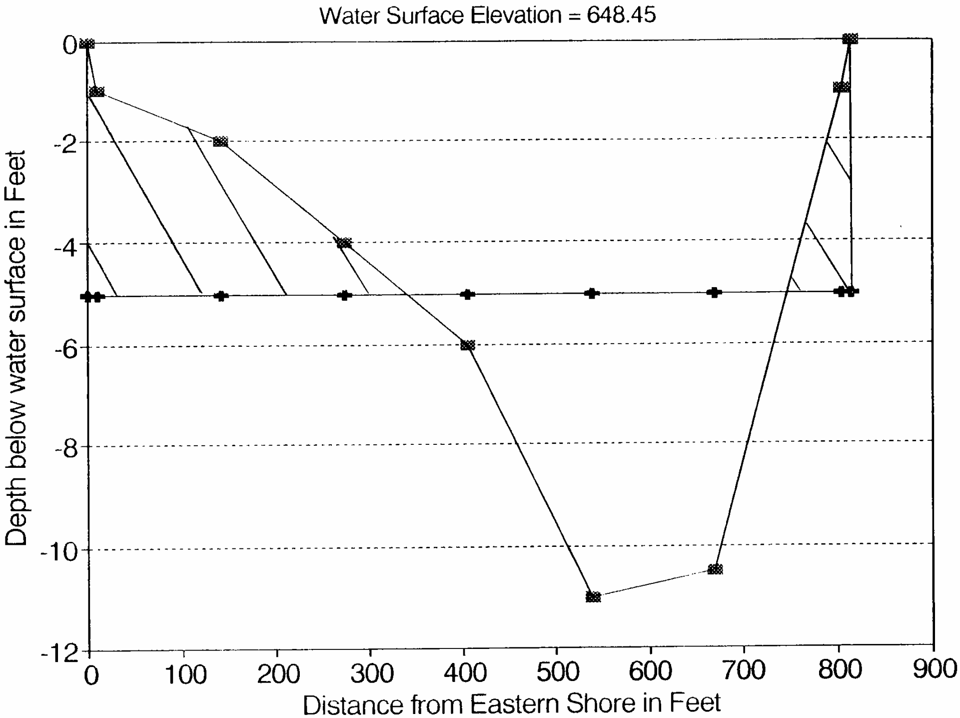
26873.5 ft. upstream along Tippecanoe River from Norway Dam



Area to be dredged

CROSS SECTION OF TRANSECT NO. 25

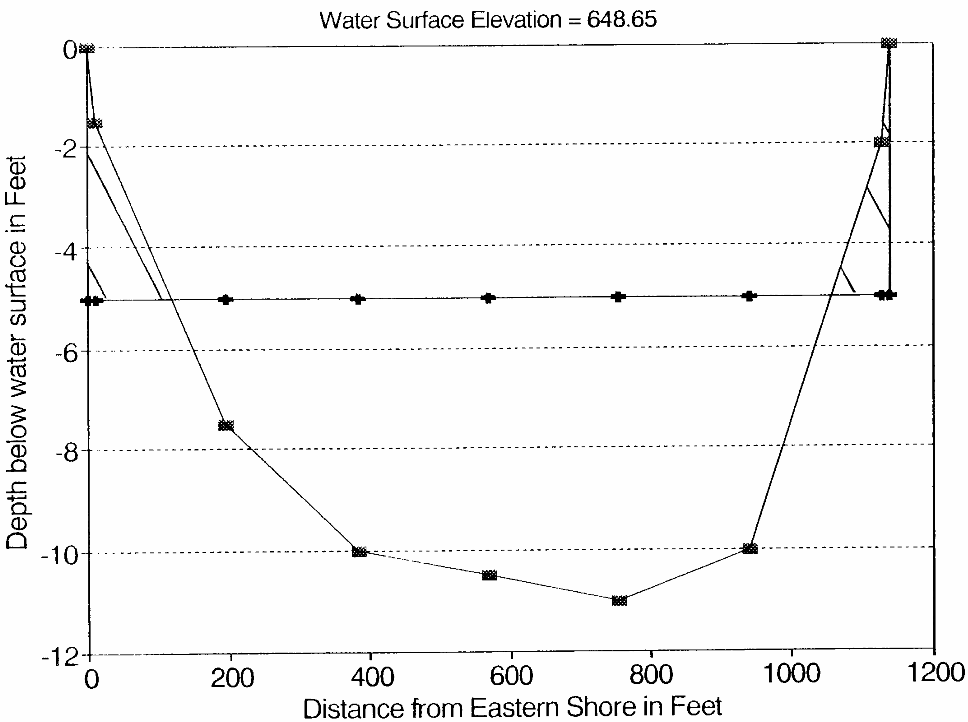
23479.5 ft. upstream along Tippecanoe River from Norway Dam



Area to be dredged

CROSS SECTION OF TRANSECT NO. 28

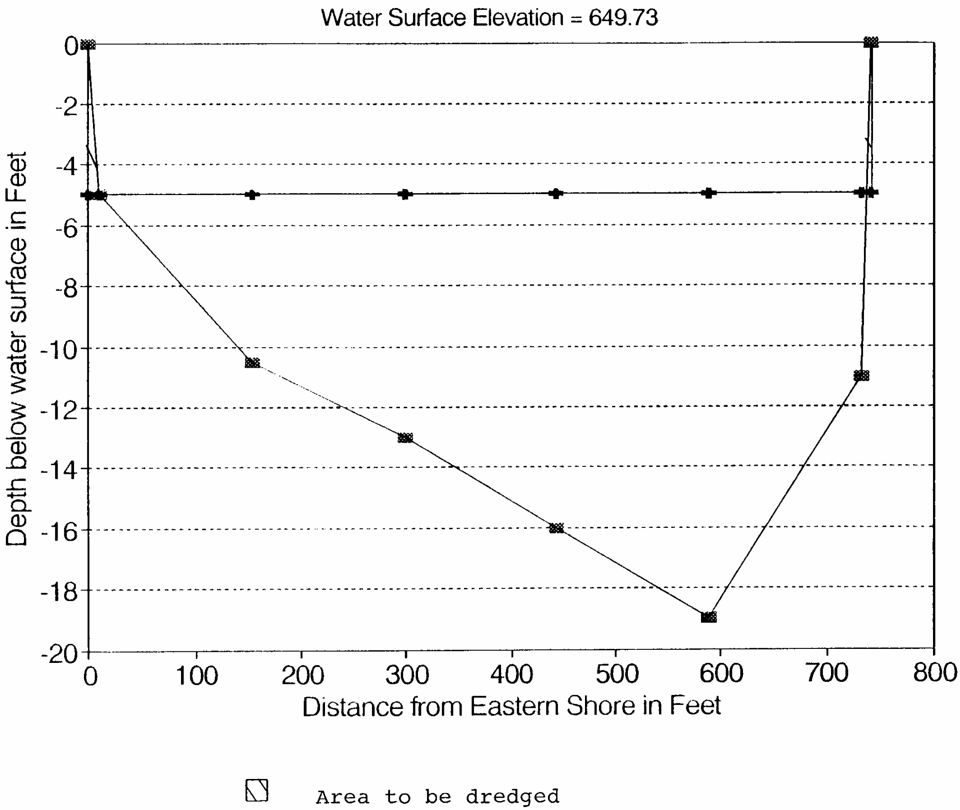
19470.0 ft. upstream along Tippecanoe River from Norway Dam



Area to be dredged

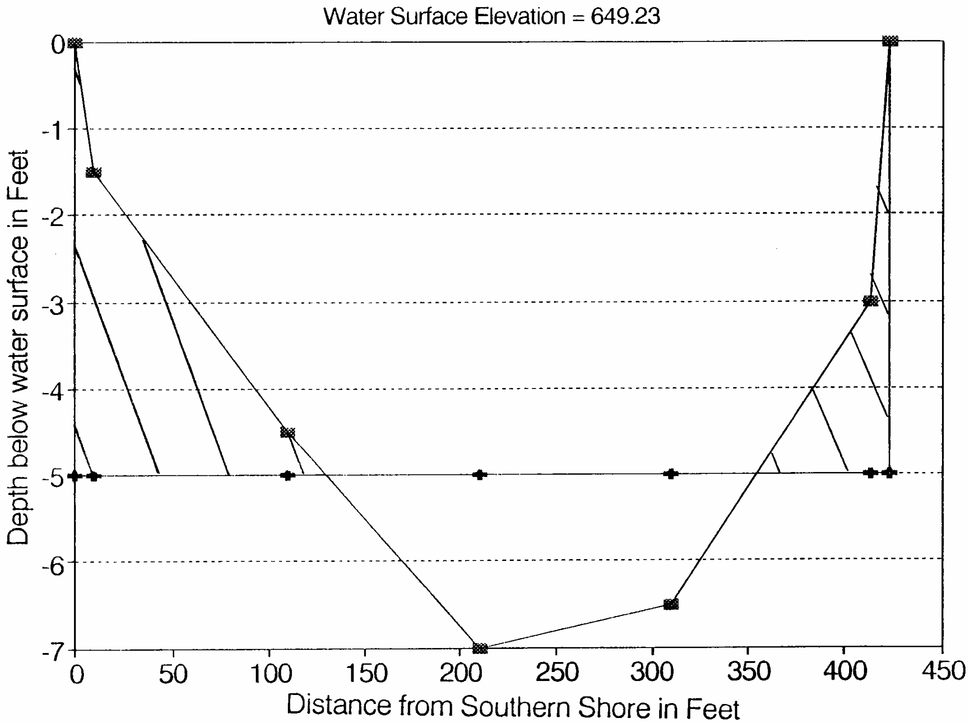
CROSS SECTION OF TRANSECT NO. 32

14201.0 ft. upstream along Tippecanoe River from Norway Dam



CROSS SECTION OF TRANSECT NO. 36

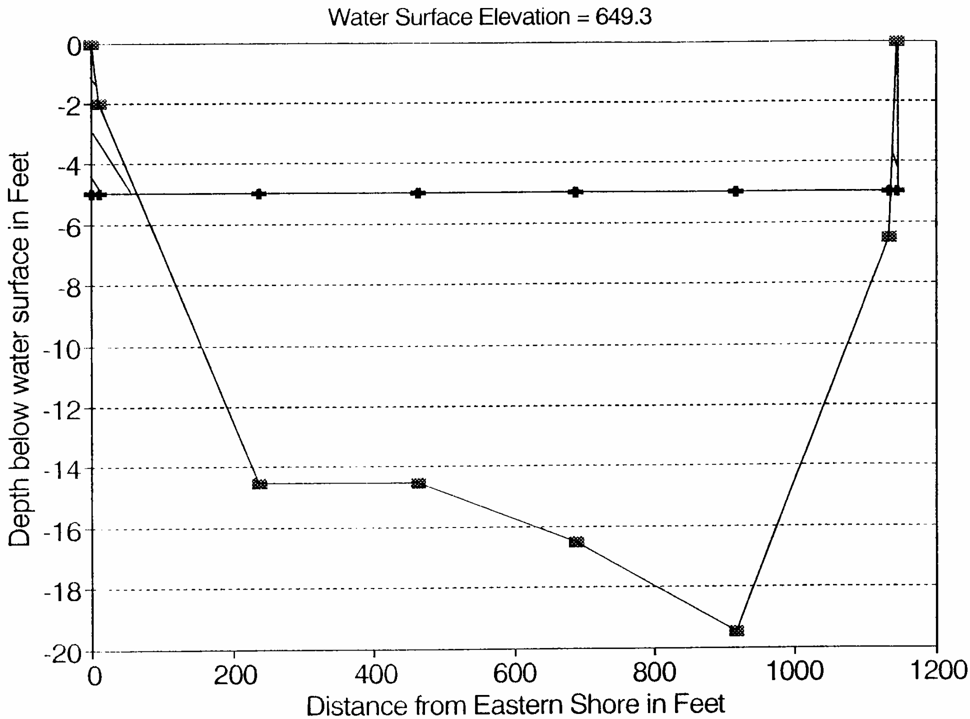
1903.0 ft. upstream along Keans Bay from the mouth



Area to be dredged

CROSS SECTION OF TRANSECT NO. 37

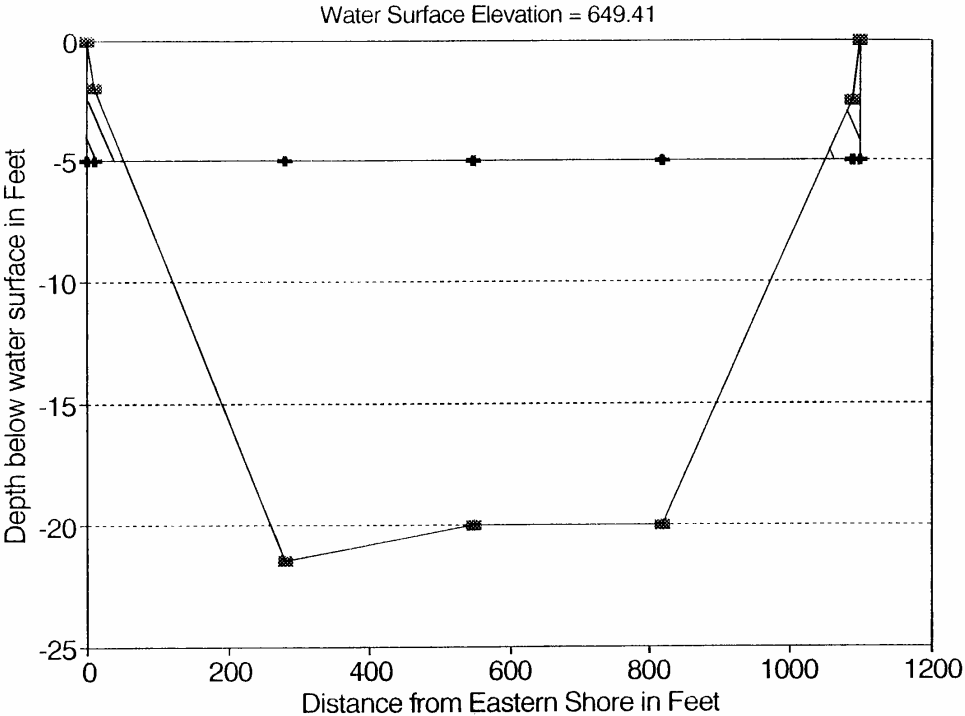
9735.0 ft. upstream along Tippecanoe River from Norway Dam



Area to be dredged

CROSS SECTION OF TRANSECT NO. 39

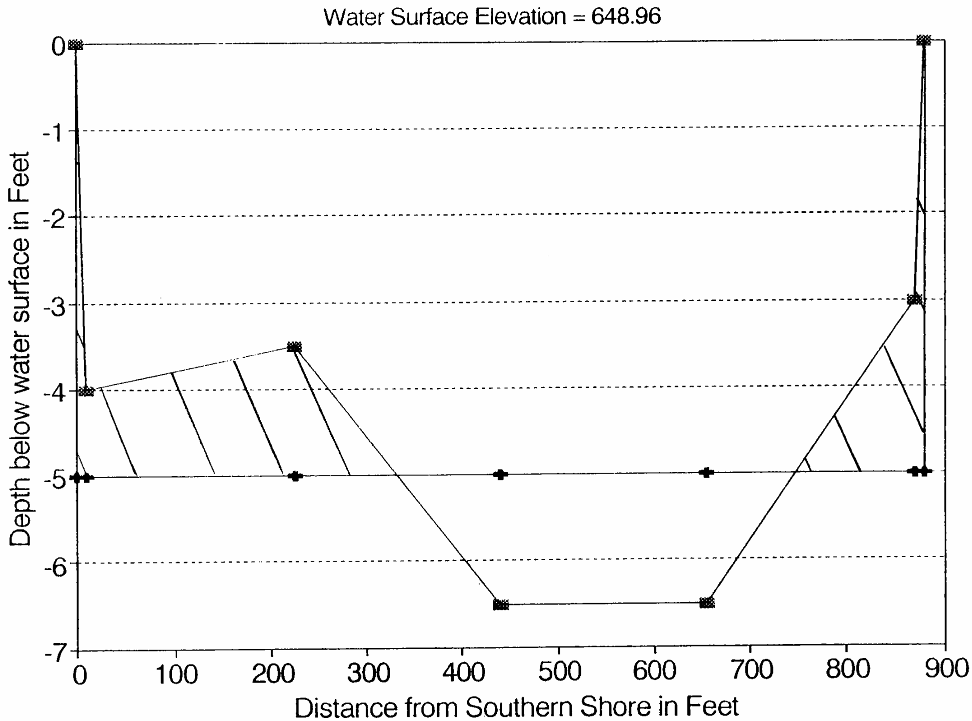
5500.0 ft. upstream along Tippecanoe River from Norway Dam



Area to be dredged

CROSS SECTION OF TRANSECT NO. 44

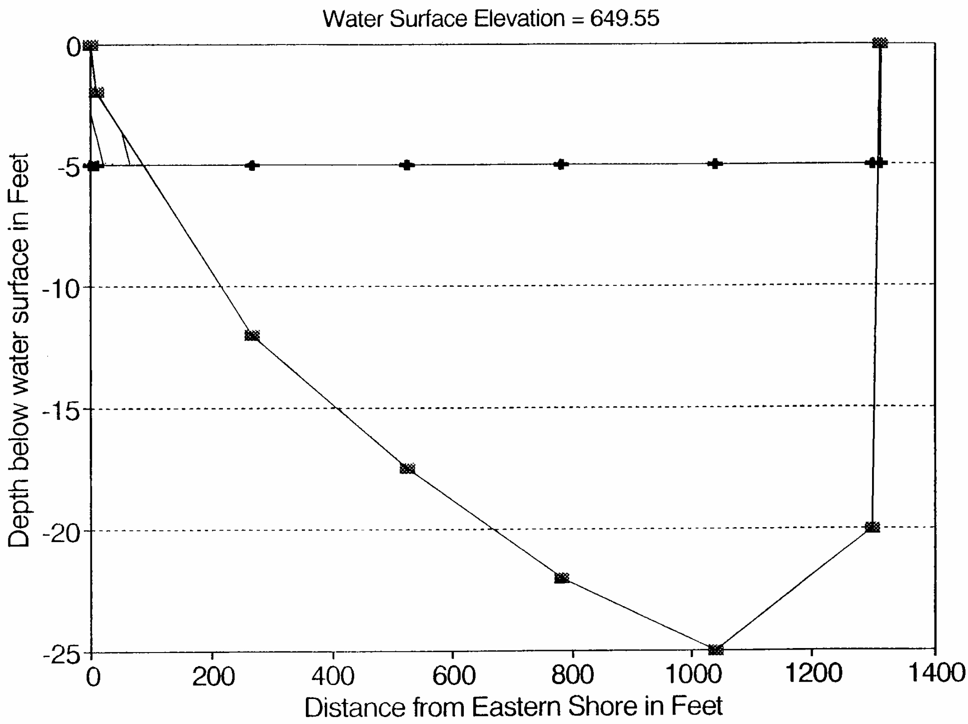
1842.5 ft. upstream along Honey Creek Bay from the mouth



Area to be dredged

CROSS SECTION OF TRANSECT NO. 46

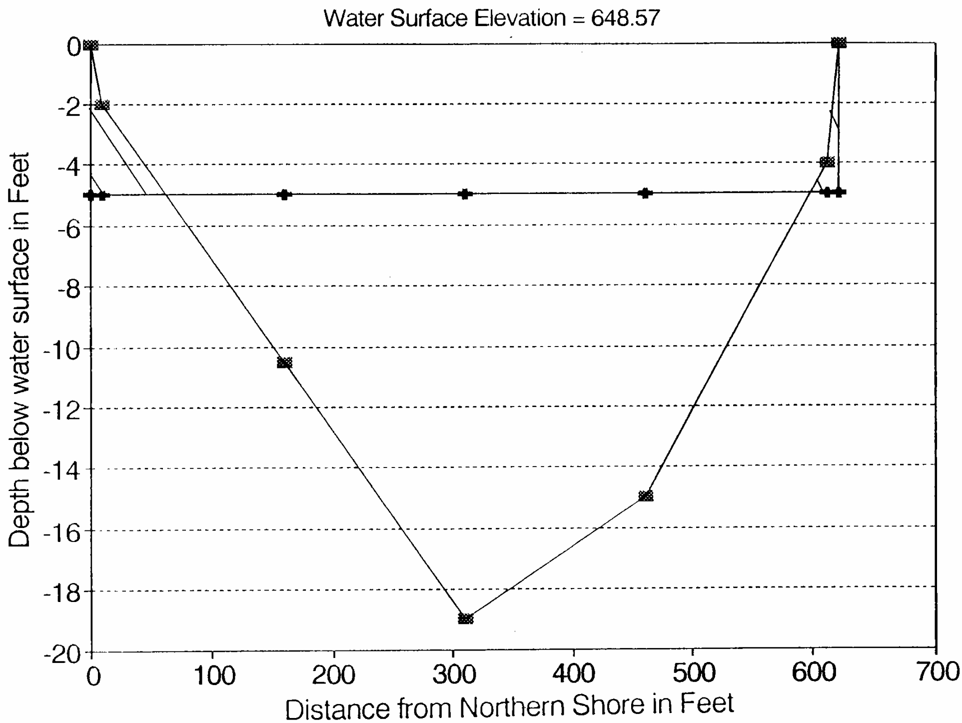
1100.0 ft. upstream along Tippecanoe River from Norway Dam



Area to be dredged

CROSS SECTION OF TRANSECT NO. 49

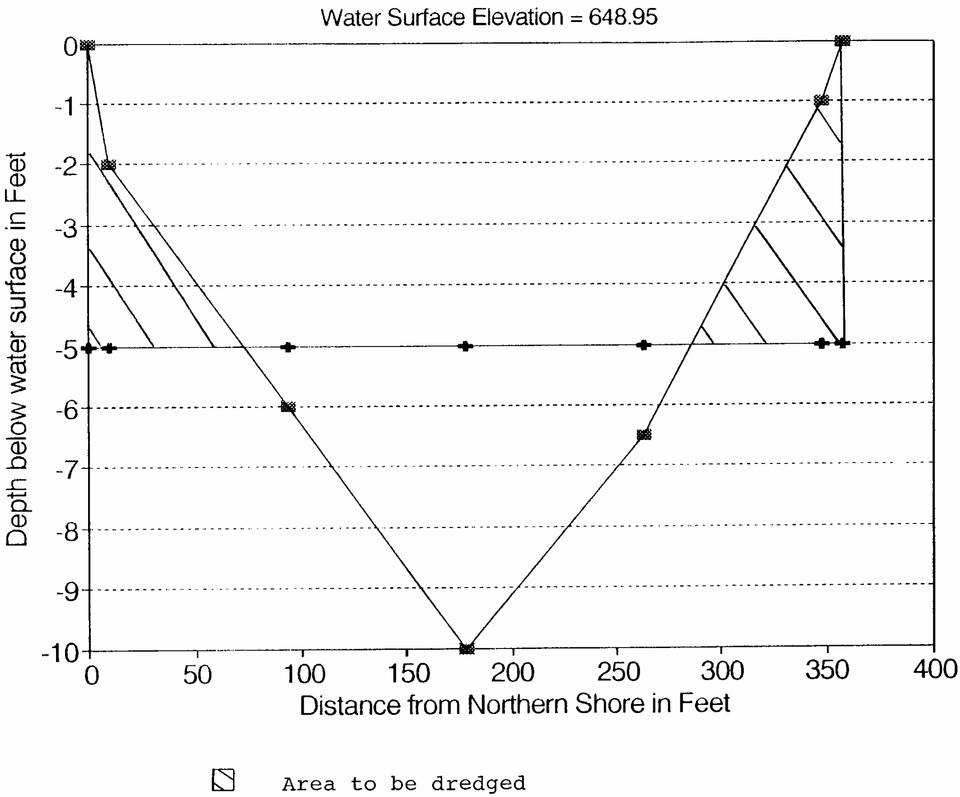
75.0 ft. upstream along Big Monon Bay (Creek) from the mouth



Area to be dredged

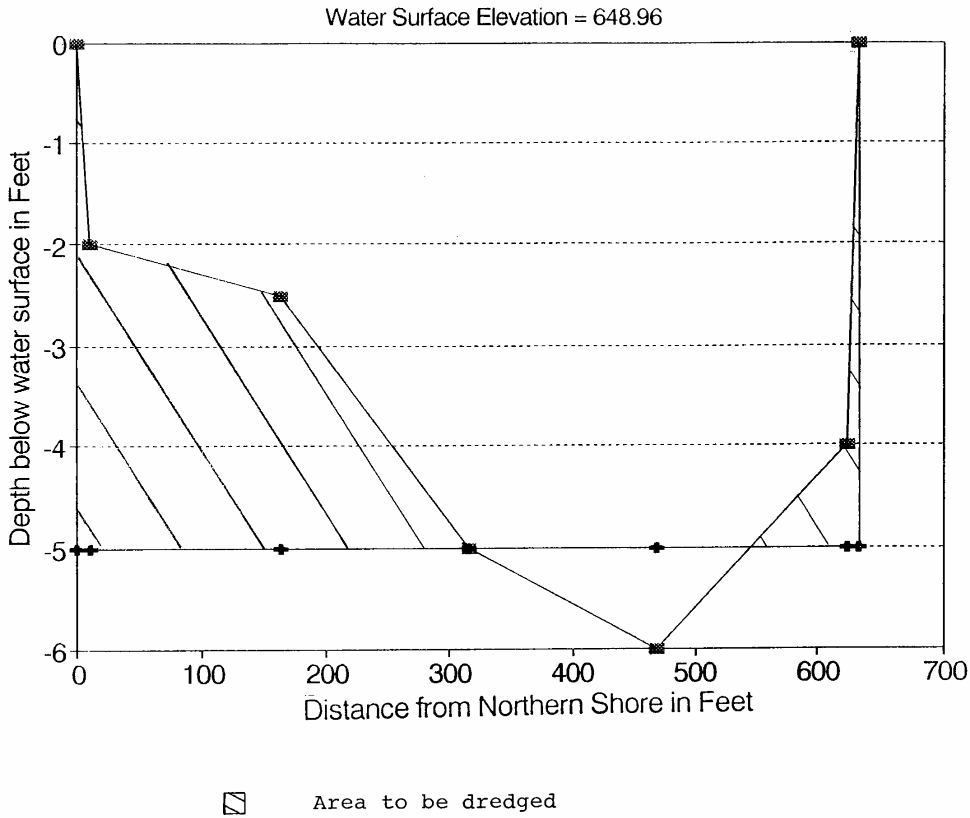
CROSS SECTION OF TRANSECT NO. 56

5151.5 ft. upstream along Big Monon Bay (Creek) from the mouth



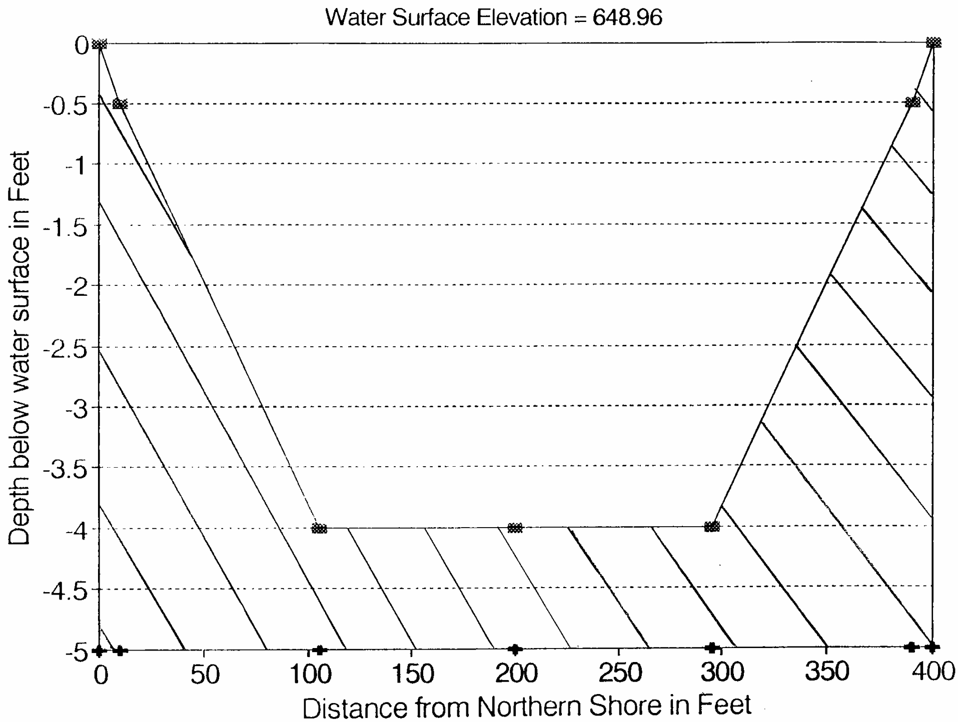
CROSS SECTION OF TRANSECT NO. 60-A

9942.0 ft. upstream along Big Monon Bay (Creek) from the mouth



CROSS SECTION OF TRANSECT NO. 63

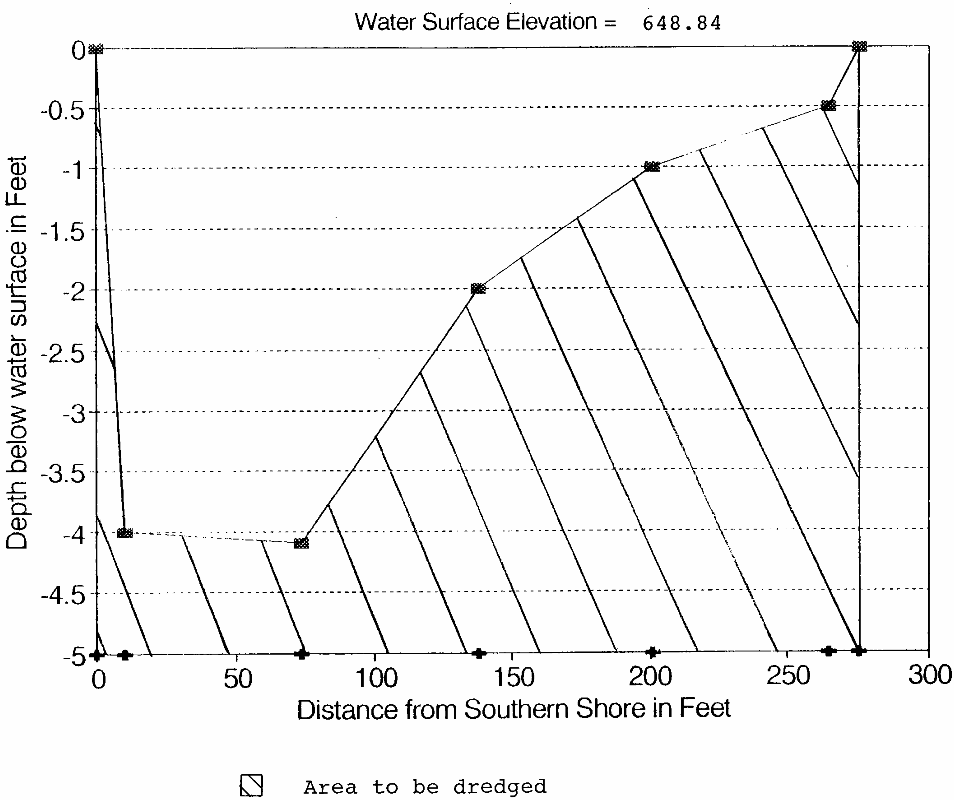
11064.5 ft. upstream along Big Monon Bay (Creek) from the mouth



Area to be dredged

CROSS SECTION OF TRANSECT NO. 66

330.0 ft. upstream along Hoaglana Bay from the mouth



APPENDIX C

STORAGE CAPACITY COMPUTATIONS OF LAKE SHAFER (1993)

Storage Capacity calculation for Lake Shafer and it's tributaries

Transect	Area(sq.ft.)	Lake Shafer Area(acre	Distance(ft)	Volume(cu.ft.)	Volume(ac.ft.)
23	4843.8	0.111			
			726.0	3319961.7	76.2
24	4302.1	0.099			
			924.0	4101451.2	94.2
25	4575.5	0.105			
			1507.0	8106981.9	186.1
26	6183.6	0.142			
			935.0	6661734.8	152.9
27	8066.1	0.185			
			1567.5	13750110.0	315.7
28	9477.9	0.218			
			1127.5	10068011.3	231.1
29	8381.1	0.192			
			1650.0	15626407.5	358.7
30	10560	0.242			
			770.0	10271261.0	235.8
31	16118.6	0.370			
			1721.5	22214149.9	510.0
32	9689.3	0.222			
			2777.5	33488595.3	768.8
33	14424.9	0.331			
			1688.5	25364056.0	582.3
37	15618.4	0.359			
			2035.0	33201432.0	762.2
38	17012	0.391			
			2200.0	37671700.0	864.8
39	17235	0.396			
			863.5	13210082.1	303.3
40	13361.6	0.307			
			1336.5	20081179.8	461.0
41	16688.8	0.383			
			1045.0	15527341.5	356.5
45	13028.6	0.299			
			1155.0	20614497.8	473.2
46	22667.5	0.520			
			1100.0	21688920.0	497.9
47	16766.9	0.385			
			SUM =	**293278953.6**	**6732.8**

Tippicanoe River

Transec	Area(sq.ft.)	Area(acre	Distance(ft)	Volume(cu.ft.)	Volume(ac.ft.)
1	881.9	0.020			
			385.0	463405.3	10.6
2	1525.4	0.035			
			1595.0	2580231.5	59.2
3	1710.0	0.039			
			984.5	1888517.1	43.4
5	2126.5	0.049			
			291.5	566238.8	13.0
6	1758.5	0.040			
			2711.5	4485770.0	103.0
7	1550.2	0.036			
			1017.5	2847982.5	65.4
8	4047.8	0.093			
			621.5	1814345.0	41.7
9	1790.8	0.041			
			968.0	1911896.8	43.9
10	2159.4	0.050			
			1127.5	3211514.6	73.7
12	3537.3	0.081			
			676.5	2107635.8	48.4
13	2693.7	0.062			
			1138.5	2534585.6	58.2
14	1758.8	0.040			
			946.0	1908034.7	43.8
15	2275.1	0.052			
			1292.5	4032600.0	92.6
16	3965.0	0.091			
			1457.5	6460368.8	148.3
18	4900.0	0.112			
			550.0	2362497.5	54.2
19	3690.9	0.085			
			1617.0	6127136.4	140.7
20	3887.5	0.089			
			869.0	4445239.2	102.0
22	6343.2	0.146			
			SUM =	**49747999.4**	**1142.1**

Hoaglana Bay

Transect	Area(sq.ft.)	Area(acre	Distance(ft)	Volume(cu.ft.)	Volume(ac.ft.)
48	3181.3	0.073			
			330.0	627033.0	14.4
66	618.9	0.014			
			SUM =	**627033.0**	**14.4**

Keans Bay

Transect	Area(sq.ft.)	Area(acre	Distance(ft)	Volume(cu.ft.)	Volume(ac.ft.)
34	3830.6	0.088			
			896.5	4150436.4	95.3
35	5428.6	0.125			
			1006.5	3770701.3	86.6
36	2064.1	0.047			
			SUM =	**7921137.7**	**181.8**

Honey Creek Bay

Transect	Area(sq.ft.)	Area(acre	Distance(ft)	Volume(cu.ft.)	Volume(ac.ft.)
42	5528.0	0.127			
			907.5	4605789.4	105.7
43	4622.5	0.106			
			935.0	4187631.3	96.1
44	4335.0	0.100			
			SUM =	**8793420.6**	**201.9**

Big Monon Bay

Transect	Area(sq.ft.)	Area(acre	Distance(ft)	Volume(cu.ft.)	Volume(ac.ft.)
49	7173.1	0.165			
			715.0	4237840.8	97.3
50	4681.0	0.107			
			605.0	3258983.8	74.8
51	6092.5	0.140			
			924.0	5463288.6	125.4
53	5732.8	0.132			
			852.5	7544838.1	173.2
54	11967.7	0.275			
			1980.0	13867425.0	318.4
56	2039.8	0.047			
			1540.0	4148298.0	95.2
59	3347.6	0.077			
			1721.5	4641680.5	106.6
60	2045.0	0.047			
			1529.0	3522586.7	80.9
60A	2562.7	0.059			
			852.5	1912498.5	43.9
61	1924.1	0.044			
			357.5	635527.8	14.6
62	1631.3	0.037			
			770.0	1127203.0	25.9
64	1296.5	0.030			
			0	0.0	0.0

65	1097	0.025	600	686850.0	15.8
63	1192.5	0.027			
			SUM =	**51047020.6**	**1171.9**

Storage Capacity of Lake Shafer and it's tributaries is **9444.8** acres-ft.

APPENDIX D

INPUT AND OUTPUT OF A TYPICAL SEDIMOT-II COMPUTER SIMULATION

```
;SSSSSSSS   8888888888888888888888888888888888888888888888888888888888888888888888888888888888888888888888888888   SSSSSSSSSS
;SSSSSSSS   888888888888888888888888  Digital Equipment Corporation - VAX/VMS Version V5.5-2  888888888888888888888888   SSSSSSSSSS
SSSSSSSSSS  8888888888888888888888888888888888888888888888888888888888888888888888888888888888888888888888888888   SSSSSSSSSS
```

```
DDDD   EEEEE  N   N  4  4   000
D   D  E      N   N  4  4  0   0
D   D  E      NN  N  4  4  0  00
D   D  EEEE   N N N  44444 0 0 0
D   D  E      N  NN     4  00  0
D   D  E      N   N     4  0   0
DDDD   EEEEE  N   N     4   000
```

```
  SSSSSSSS  EEEEEEEEEE  DDDDDDDD      IIIIII    MM      MM    000000    TTTTTTTTTT
  SSSSSSSS  EEEEEEEEEE  DDDDDDDD      IIIIII    MM      MM    000000    TTTTTTTTTT
SS          EE          DD      DD      II      MMMM  MMMM  00      00      TT
SS          EE          DD      DD      II      MMMM  MMMM  00      00      TT
SS          EE          DD      DD      II      MM  MM  MM  00      00      TT
SS          EE          DD      DD      II      MM  MM  MM  00      00      TT
  SSSSSS    EEEEEEEE    DD      DD      II      MM      MM  00      00      TT
  SSSSSS    EEEEEEEE    DD      DD      II      MM      MM  00      00      TT
        SS  EE          DD      DD      II      MM      MM  00      00      TT
        SS  EE          DD      DD      II      MM      MM  00      00      TT
        SS  EE          DD      DD      II      MM      MM  00      00      TT
        SS  EE          DD      DD      II      MM      MM  00      00      TT
SSSSSSSS    EEEEEEEEEE  DDDDDDDD      IIIIII    MM      MM    000000        TT
SSSSSSSS    EEEEEEEEEE  DDDDDDDD      IIIIII    MM      MM    000000        TT
```

```
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        DDDDDDDD      AAAAAA    TTTTTTTTTT      ;;;;      666666
        DD      DD  AA      AA      TT          ;;;;    66
        DD      DD  AA      AA      TT          ;;;;    66
        DD      DD  AA      AA      TT                  66
        DD      DD  AA      AA      TT                  66
        DD      DD  AA      AA      TT          ;;;;    66666666
        DD      DD  AA      AA      TT          ;;;;    66666666
        DD      DD  AAAAAAAAAA      TT          ;;;;    66      66
        DD      DD  AAAAAAAAAA      TT          ;;;;    66      66
....    DD      DD  AA      AA      TT            ;;    66      66
....    DD      DD  AA      AA      TT            ;;    66      66
....    DDDDDDDD    AA      AA      TT          ;;        666666
....    DDDDDDDD    AA      AA      TT          ;;        666666
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ile _1DIA1:[DEN40.SEDIMOD]SEDIMOT.DAT;6 (206,20,0), last revised on 7-OCT-1993 14:06, is a 5 block sequential file owned by UIC [DEN40]. The records are variable length with implied (CR) carriage control. The longest record is 80 bytes.

ob SEDIMOT (249) queued to CHI$PRINT on 8-OCT-1993 15:08 by user DEN40, UIC [DEN40], under account DEN40 at priority 100, started n printer LTA303 on 8-OCT-1993 15:08 from queue CHI$PRINT.


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SSSSSSSSS   888888888888888888888888  Digital Equipment Corporation - VAX/VMS Version V5.5-2  888888888888888888888888   SSSSSSSSSS
SSSSSSSSS   8888888888888888888888888888888888888888888888888888888888888888888888888888888888888888888888888888   SSSSSSSSSS
```

HONEY CREEK SEDIMOT 2 ANALYSIS

```
    2       2
 2.83     24.     0.1     2.2
    2       2
    2       1
 1.37     1.5    1.25
    2      14
  4.8     2.0    0.41    0.17   0.074    .037    .025    .013     .01   0.007
 .003    .002    .001   .0001
 100.     98.     94.     60.     30.     17.     12.     10.      9.      7.
   6.      4.      .1     .01
 100.     98.     94.     58.     29.     17.     13.      9.      8.      6.
   4.      3.      .1     .01
    1       1
   0.      0.      0.
   0.      0.      0.
    1
 0.20    0.08    0.28
    5       1       1       1       1
2560.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      1.
2560.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      1.
2560.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      1.
2560.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      1.
2560.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      1.
    5       1       1       1       1
2560.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      2.
2560.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      2.
2560.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      2.
2560.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      2.
2560.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      2.
    0       2       1       1       1
  0.1     1.5      0.
    1       0       8     500       1       1       2
   0.      1.      3.      5.      7.      9.     11.     14.
   0.   5.510  12.640  14.640  15.790  17.260  18.880  19.380
   0.      0.      0.      0.      0.      0.   2421.   5264.
```

```
DDDD   EEEEE  N   N  4  4   000
D   D  E      N   N  4  4  0   0
D   D  E      NN  N  4  4  0  00
D   D  EEEE   N N N  44444 0 0 0
D   D  E      N  NN     4  00  0
D   D  E      N   N     4  0   0
DDDD   EEEEE  N   N     4   000
```

```
  SSSSSSSS  EEEEEEEEEE  DDDDDDDD    IIIIII  MM      MM   000000    TTTTTTTTTT
  SSSSSSSS  EEEEEEEEEE  DDDDDDDD    IIIIII  MM      MM   000000    TTTTTTTTTT
SS          EE          DD      DD    II    MMMM  MMMM  OO      OO     TT
SS          EE          DD      DD    II    MMMM  MMMM  OO      OO     TT
SS          EE          DD      DD    II    MM  MM  MM  OO      OO     TT
SS          EE          DD      DD    II    MM  MM  MM  OO      OO     TT
  SSSSSS    EEEEEEEE    DD      DD    II    MM      MM  OO      OO     TT
  SSSSSS    EEEEEEEE    DD      DD    II    MM      MM  OO      OO     TT
        SS  EE          DD      DD    II    MM      MM  OO      OO     TT
        SS  EE          DD      DD    II    MM      MM  OO      OO     TT
        SS  EE          DD      DD    II    MM      MM  OO      OO     TT
        SS  EE          DD      DD    II    MM      MM  OO      OO     TT
SSSSSSSS    EEEEEEEEEE  DDDDDDDD    IIIIII  MM      MM   000000        TT
SSSSSSSS    EEEEEEEEEE  DDDDDDDD    IIIIII  MM      MM   000000        TT
```

```
          000000    UU      UU  TTTTTTTTTT    ;;;;      11
          000000    UU      UU  TTTTTTTTTT    ;;;;      11
        OO      OO  UU      UU      TT        ;;;;    1111
        OO      OO  UU      UU      TT        ;;;;    1111
        OO      OO  UU      UU      TT                  11
        OO      OO  UU      UU      TT                  11
        OO      OO  UU      UU      TT        ;;;;      11
        OO      OO  UU      UU      TT        ;;;;      11
        OO      OO  UU      UU      TT        ;;;;      11
        OO      OO  UU      UU      TT        ;;;;      11
  ....  OO      OO  UU      UU      TT          ;;      11
  ....  OO      OO  UU      UU      TT          ;;      11
  ....    000000    UUUUUUUUUU      TT        ;;    111111
  ....    000000    UUUUUUUUUU      TT        ;;    111111
```

File _1DIA1:[DEN40.SEDIMOD]SEDIMOT.OUT;1 (282,50,0), last revised on 7-OCT-1993 14:06, is a 37 block sequential file owned by UIC [DEN40]. The records are variable length with FORTRAN (FTN) carriage control. The longest record is 80 bytes.

Job SEDIMOT (247) queued to CHI$PRINT on 8-OCT-1993 15:07 by user DEN40, UIC [DEN40], under account DEN40 at priority 100, started on printer LTA303 on 8-OCT-1993 15:07 from queue CHI$PRINT.

RRRRRRRRRR 77777777777777777777777777777777777777777777777777777777777777777777777777777777777777777777777777777777 RRRRRRRRRR
RRRRRRRRRR 777777777777777777777777 Digital Equipment Corporation - VAX/VMS Version V5.5-2 777777777777777777777777 RRRRRRRRRR
RRRRRRRRRR 77777777777777777777777777777777777777777777777777777777777777777777777777777777777777777777777777777777 RRRRRRRRRR

```
*******************************************************************
*******************************************************************

       UNIVERSITY OF KENTUCKY COMPUTER MODEL
       OF SURFACE MINE HYDROLOGY AND SEDIMENTOLOGY
       FOR MORE INFORMATION CONTACT THE AGRICULTURAL
       ENGINEERING DEPARTMENT

       THE UK MODEL IS A DESIGN MODEL DEVELOPED TO PREDICT
       THE HYDRAULIC AND SEDIMENT RESPONSE FROM SURFACE
       MINED LANDS FOR A SPECIFIED RAINFALL EVENT (SINGLE STORM)

       VERSION DATE 9-23-83

       DISCLAIMER: NEITHER THE UNIVERSITY NOR ANY OF ITS EMPLOYEES
       ACCEPT ANY RESPONSIBILITY OR LEGAL LIABILITY FOR THE
       CONCLUSIONS DRAWN FROM THE RESULTS OF THIS MODEL

*******************************************************************
*******************************************************************


*******************************************************************
*                                                                 *
*     THE FOLLOWING VALUES ARE NOW PREDICTED BY SEDIMOT II.       *
*     THEY CAN BE FOUND IN SUMMARY TABLES.                        *
*      1. PERIOD OF SIGNIFICANT CONCENTRATION                     *
*      2. VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION        *
*         DURING PERIOD OF SIGNIFICANT CONCENTRATION              *
*      3. VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION        *
*         DURING PEAK 24 HOUR PERIOD                              *
*      4. ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING      *
*         PERIOD OF SIGNIFICANT CONCENTRATION                     *
*      5. ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION             *
*         DURING PEAK 24 HOUR PERIOD                              *
*                                                                 *
*     ALL CONCENTRATIONS ARE IN ML/L.                             *
*                                                                 *
*******************************************************************


              **********************************************

                  WATERSHED IDENTIFICATION CODE
                  ------------------------------
                     HONEY CREEK SEDIMOT 2 ANALYSIS

              **********************************************
```

INPUT PARTICLE SIZE-PERCENT FINER DISTRIBUTIONS

```
SIZE,MM              4.800  2.000  0.410  0.170  0.074  0.037
                     0.025  0.013  0.010  0.007  0.003  0.002
                     0.001  0.000
```

!!!!!!!!!!!!!!!!!!!!!!!!!!! W A R N I N G !!!!!!!!!!!!!!!!!!!!!!!!!!

LAST PERCENT FINER VALUE
IS NOT WITHIN THE EXPECTED LIMITS. THE
VALUE MUST BE NO SMALLER THAN 0.0000 AND IF POSSIBLE SHOULD NOT EXCEED
0.000. SEDIMOT WILL CONTINUE WITH THE VALUE ENTERED, 0.0100 ,BUT IT
MAY CAUSE INACCURACIES OR EVEN TERMINATION LATER IN THE PROGRAM

!!

```
PCT FINER NO. 1  100.000 98.000 94.000 60.000 30.000 17.000
                  12.000 10.000  9.000  7.000  6.000  4.000
                   0.100  0.010
```

!!!!!!!!!!!!!!!!!!!!!!!!!!! W A R N I N G !!!!!!!!!!!!!!!!!!!!!!!!!!

LAST PERCENT FINER VALUE
IS NOT WITHIN THE EXPECTED LIMITS. THE
VALUE MUST BE NO SMALLER THAN 0.0000 AND IF POSSIBLE SHOULD NOT EXCEED
0.000. SEDIMOT WILL CONTINUE WITH THE VALUE ENTERED, 0.0100 ,BUT IT
MAY CAUSE INACCURACIES OR EVEN TERMINATION LATER IN THE PROGRAM

!!

```
PCT FINER NO. 2  100.000 98.000 94.000 58.000 29.000 17.000
                  13.000  9.000  8.000  6.000  4.000  3.000
                   0.100  0.010
```

*********************INPUT VALUES*********************

STORM DURATION	=	24.00	HOURS
PRECIPATION DEPTH	=	2.83	INCHES
SPECIFIC GRAVITY	=	1.37	
LOAD RATE EXPONENT FACTOR	=	1.50	
SUBMERGED BULK SPECIFIC GRAVITY	=	1.25	

* *

JUNCTION 1, BRANCH 1, STRUCTURE 1

* *

****

BETA IS NEGATIVE WHICH INHERENTLY INDICATES THAT THE STREAM SYSTEM TRANSPORT CAPACITY EXCEEDS THE SEDIMENT LOAD, AS EVALUATED BY WILLIAMS' TECHNIQUE. SEDIMOT II DOES NOT CONSIDER ERODIBLE CHANNELS SO BETA IS SET EQUAL TO .01. IF THE USER WISHES TO EVALUATE THE TRANSPORT CAPACITY OF THE STREAM DIRECTLY HE/SHE SHOULD USE SUBROUTINE SLOSS.

****

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	2560.00	60.00	3.000	3.000	0.000	0.00	2.0
2	2560.00	60.00	3.000	3.000	0.000	0.00	2.0
3	2560.00	60.00	3.000	3.000	0.000	0.00	2.0
4	2560.00	60.00	3.000	3.000	0.000	0.00	2.0
5	2560.00	60.00	3.000	3.000	0.000	0.00	2.0

*** SEDIMENT INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	SEG NUM	SOIL K	LENGTH FEET	SLOPE PCT	CP VALUE	PART OPT	SURF COND
1	1	0.10	700.0	0.10	1.000	1.0	0.0
2	1	0.10	700.0	0.10	1.000	1.0	0.0
3	1	0.10	700.0	0.10	1.000	1.0	0.0
4	1	0.10	700.0	0.10	1.000	1.0	0.0
5	1	0.10	700.0	0.10	1.000	1.0	0.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)	SEDIMENT TONS	DIAM (MM)	DELIVERY RATIO 1	DELIVERY RATIO 2
1	78.91	0.27	147.20	0.030	0.287	0.995
2	78.91	0.27	147.20	0.030	0.287	0.995
3	78.91	0.27	147.20	0.030	0.287	0.995
4	78.91	0.27	147.20	0.030	0.287	0.995
5	78.91	0.27	147.20	0.030	0.287	0.995

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	292.6924	ACRE-FT
PEAK DISCHARGE	=	394.5471	CFS
AREA	=	12800.0000	ACRES

TIME OF PEAK DISCHARGE	=	14.70	HRS
BETA	=	0.0100	
RAINFALL EROSITIVITY FACTOR	=	46.36	EI UNIT
PEAK CONCENTRATION	=	2365.41	MG/L
PEAK SETTLEABLE CONCENTRATION	=	1.29	ML/L
PEAK SETTLEABLE CONCENTRATION	=	1613.76	MG/L
TOTAL SEDIMENT YIELD	=	732.1619	TONS
REPRESENTATIVE PARTICLE SIZE	=	0.0299	MM
TIME OF PEAK CONCENTRATION	=	14.70	HRS
PERIOD OF SIGNIFICANT CONCENTRATION	=	24.70	HRS
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	1.00	ML/L
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	1.00	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	0.67	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	0.69	ML/L

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NULL STRUCTURE

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* *
JUNCTION 1, BRANCH 2, STRUCTURE 1
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BETA IS NEGATIVE WHICH INHERENTLY INDICATES THAT THE STREAM SYSTEM TRANSPORT CAPACITY EXCEEDS THE SEDIMENT LOAD, AS EVALUATED BY WILLIAMS' TECHNIQUE. SEDIMOT II DOES NOT CONSIDER ERODIBLE CHANNELS SO BETA IS SET EQUAL TO .01. IF THE USER WISHES TO EVALUATE THE TRANSPORT CAPACITY OF THE STREAM DIRECTLY HE/SHE SHOULD USE SUBROUTINE SLOSS.

****

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	2560.00	60.00	3.000	3.000	0.000	0.00	2.0
2	2560.00	60.00	3.000	3.000	0.000	0.00	2.0
3	2560.00	60.00	3.000	3.000	0.000	0.00	2.0
4	2560.00	60.00	3.000	3.000	0.000	0.00	2.0
5	2560.00	60.00	3.000	3.000	0.000	0.00	2.0

*** SEDIMENT INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	SEG NUM	SOIL K	LENGTH FEET	SLOPE PCT	CP VALUE	PART OPT	SURF COND
1	1	0.10	700.0	0.10	1.000	2.0	0.0
2	1	0.10	700.0	0.10	1.000	2.0	0.0
3	1	0.10	700.0	0.10	1.000	2.0	0.0
4	1	0.10	700.0	0.10	1.000	2.0	0.0
5	1	0.10	700.0	0.10	1.000	2.0	0.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)	SEDIMENT TONS	DIAM (MM)	DELIVERY RATIO 1	DELIVERY RATIO 2
1	78.91	0.27	147.20	0.029	0.287	0.995
2	78.91	0.27	147.20	0.029	0.287	0.995
3	78.91	0.27	147.20	0.029	0.287	0.995
4	78.91	0.27	147.20	0.029	0.287	0.995
5	78.91	0.27	147.20	0.029	0.287	0.995

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	292.6924	ACRE-FT
PEAK DISCHARGE	=	394.5471	CFS
AREA	=	12800.0000	ACRES

TIME OF PEAK DISCHARGE	=	14.70	HRS
BETA	=	0.0100	
RAINFALL EROSITIVITY FACTOR	=	46.36	EI UNIT
PEAK CONCENTRATION	=	2365.72	MG/L
PEAK SETTLEABLE CONCENTRATION	=	1.36	ML/L
PEAK SETTLEABLE CONCENTRATION	=	1697.07	MG/L
TOTAL SEDIMENT YIELD	=	732.2594	TONS
REPRESENTATIVE PARTICLE SIZE	=	0.0284	MM
TIME OF PEAK CONCENTRATION	=	14.70	HRS
PERIOD OF SIGNIFICANT CONCENTRATION	=	24.70	HRS
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	1.05	ML/L
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	1.06	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	0.71	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	0.73	ML/L

* * * * * * * * * * * *

NULL STRUCTURE

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JUNCTION 2, BRANCH 1, STRUCTURE 1

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ZERO SUBWATERSHEDS ABOVE STRUCTURE

****

**** SUMMARY TABLE OF STRUCTURE INPUT VALUES *****

TOTAL SEDIMENT YIELD	=	1464.4214	TONS
TOTAL RUNOFF VOLUME	=	585.3848	AC-FT
PEAK RUNOFF DISCHARGE	=	788.64	CFS
TOTAL DRAINAGE AREA	=	25600.00	ACRES
PEAK CONCENTRATION	=	2365.57	MG/L
PEAK SETTLEABLE CONCENTRATION	=	1.32	ML/L
PEAK SETTLEABLE CONCENTRATION	=	1655.35	MG/L
PERIOD OF SIGNIFICANT CONCENTRATION	=	24.60	HRS
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	1.03	ML/L
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	1.03	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	0.69	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	0.71	ML/L

* *

POND RESULTS

* *

***** CONTROL VARIABLES OPTIONS *****

FLOW	FRACTN	ISDO	NRHP	NSP	NCSTR
1	0	1	500	8	2

***** BASIN GEOMETRY *****

STAGE (FT)	AREA (ACRES)	AVERAGE DEPTH (FT)	DISCHARGE (CFS)	CAPACITY (ACRES-FT)
0.00	0.000	0.00	0.00	0.00
1.00	5.510	0.50	0.00	2.76
3.00	12.640	1.99	0.00	20.91
5.00	14.640	3.69	0.00	48.19
7.00	15.790	5.47	0.00	78.62
9.00	17.260	7.25	0.00	111.67
11.00	18.880	8.98	2421.00	147.81
14.00	19.380	11.62	5264.00	205.20

***** STORM EVENT SUMMARY *****

TURBULENCE FACTOR	=	1.50	
PERMANENT POOL CAPACITY	=	111.665	ACRE-FT
DEAD STORAGE	=	0.00	PERCENT
TIME INCREMENT OUTFLOW	=	0.10	HRS
VISCOSITY	=	0.009	CM**2/SEC
INFLOW RUNOFF VOLUME	=	585.385	ACRE-FT
OUTFLOW ROUTED VOLUME	=	585.385	ACRE-FT
STORM VOLUME DISCHARGED (PLUG FLOW)	=	585.385	ACRE-FT
POND VOLUME AT PEAK STAGE	=	123.377	ACRE-FT
PEAK STAGE	=	9.648	FT
PEAK INFLOW RATE	=	788.642	CFS
PEAK DISCHARGE RATE	=	784.577	CFS
PEAK INFLOW SEDIMENT CONCENTRATION	=	2365.57	MG/L
PEAK EFFLUENT SEDIMENT CONCENTRATION	=	1197.39	MG/L
PEAK EFFLUENT SETTLEABLE CONCENTRATION	=	0.3734	ML/L
PEAK EFFLUENT SETTLEABLE CONCENTRATION	=	466.76	MG/L
STORM AVERAGE EFFLUENT CONCENTRATION	=	886.20	MG/L
AVERAGE EFFLUENT SEDIMENT CONCENTRATION	=	886.20	MG/L
BASIN TRAP EFFICIENCY	=	51.93	PERCENT
DETENTION TIME OF FLOW WITH SEDIMENT	=	0.18	HRS
DETENTION TIME FROM HYDROGRAPH CENTERS	=	0.18	HRS
DETENTION TIME INCLUDING STORED FLOW	=	0.18	HRS
SEDIMENT LOAD DISCHARGED	=	703.88	TONS
PERIOD OF SIGNIFICANT CONCENTRATION	=	25.20	HRS
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	0.28	ML/L
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	0.28	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	0.22	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	0.23	ML/L

*** RUN COMPLETED ****

```
UUUUUUUU  000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000  UUUUUUUUUU
UUUUUUUU  00000000000000000000000  Digital Equipment Corporation - VAX/VMS Version V5.5-2  00000000000000000000000  UUUUUUUUUU
UUUUUUUUUU  000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000  UUUUUUUUUU
```

```
DDDD   EEEEE  N   N  4  4    000
D   D  E      N   N  4  4   0   0
D   D  E      NN  N  4  4   0  00
D   D  EEEE   N N N  44444  0 0 0
D   D  E      N  NN     4   00  0
D   D  E      N   N     4   0   0
DDDD   EEEEE  N   N     4    000
```

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HH        HH    000000      AAAAAA      GGGGGGGG
HH        HH    000000      AAAAAA      GGGGGGGG
HH        HH  OO      OO  AA      AA  GG
HH        HH  OO      OO  AA      AA  GG
HH        HH  OO      OO  AA      AA  GG
HH        HH  OO      OO  AA      AA  GG
HHHHHHHHHH  OO      OO  AA      AA  GG
HHHHHHHHHH  OO      OO  AA      AA  GG
HH        HH  OO      OO  AAAAAAAAAA  GG  GGGGGG
HH        HH  OO      OO  AAAAAAAAAA  GG  GGGGGG
HH        HH  OO      OO  AA      AA  GG      GG
HH        HH  OO      OO  AA      AA  GG      GG
HH        HH    000000    AA      AA    GGGGGG
HH        HH    000000    AA      AA    GGGGGG
```

```
     DDDDDDDD      AAAAAA     TTTTTTTTTT      ;;;;       11
     DDDDDDDD      AAAAAA     TTTTTTTTTT      ;;;;       11
     DD      DD  AA      AA       TT          ;;;;     1111
     DD      DD  AA      AA       TT          ;;;;     1111
     DD      DD  AA      AA       TT                     11
     DD      DD  AA      AA       TT                     11
     DD      DD  AA      AA       TT          ;;;;       11
     DD      DD  AA      AA       TT          ;;;;       11
     DD      DD  AAAAAAAAAA       TT          ;;;;       11
     DD      DD  AAAAAAAAAA       TT          ;;;;       11
.... DD      DD  AA      AA       TT            ;;       11
.... DD      DD  AA      AA       TT            ;;       11
.... DDDDDDDD    AA      AA       TT          ;;     111111
.... DDDDDDDD    AA      AA       TT          ;;     111111
```

ile _1DIA1:[DEN40.SEDIMOD]HOAG.DAT;1 (6110,23,0), last revised on 7-OCT-1993 12:15, is a 5 block sequential file owned by UIC DEN40]. The records are variable length with implied (CR) carriage control. The longest record is 80 bytes.

ob HOAG (251) queued to CHI$PRINT on 8-OCT-1993 15:09 by user DEN40, UIC [DEN40], under account DEN40 at priority 100, started on rinter LTA303 on 8-OCT-1993 15:09 from queue CHI$PRINT.


```
UUUUUUUUUU  000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000  UUUUUUUUUU
UUUUUUUUU  00000000000000000000000  Digital Equipment Corporation - VAX/VMS Version V5.5-2  00000000000000000000000  UUUUUUUUUU
UUUUUUUUU  000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000000  UUUUUUUUUU
```

HOAGLAND BAY SEDIMOT 2 ANALYSIS

```
    2       2
 2.83     24.     0.1     2.2
    2       2
    2       1
 1.37     1.5    1.25
    2      14
  4.8     2.0    0.41    0.17   0.074    .037    .025    .013     .01   0.007
 .003    .002    .001   .0001
 100.     98.     94.     60.     30.     17.     12.     10.      9.      7.
   6.      4.      .1     .01
 100.     98.     94.     58.     29.     17.     13.      9.      8.      6.
   4.      3.      .1     .01
    1       1
   0.      0.      0.
   0.      0.      0.
    1
 0.20    0.08    0.28
    5       1       1       1       1
4480.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      1.
4480.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      1.
4480.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      1.
4480.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      1.
4480.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      1.
    5       1       1       1       1
4480.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      2.
4480.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      2.
4480.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      2.
4480.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      2.
4480.     60.      3.      3.      0.      0.      1.      2.      0.
  .10    700.     0.1      1.      2.
    0       2       1       1       1
  0.1     1.5      0.
    1       0       9     500       1       1       2
   0.      2.      4.      6.      8.     10.     12.     14.    15.5
   0.   3.840   7.960   8.550   9.130   9.630  10.100  10.570  10.870
   0.      0.      0.      0.      0.      0.   4690.   7490.   9535.
```

```
TTTTTTTT     9999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999     TTTTTTTTTT
TTTTTTTT     9999999999999999999999999  Digital Equipment Corporation - VAX/VMS Version V5.5-2  9999999999999999999999999     TTTTTTTTTT
TTTTTTTTTT   9999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999     TTTTTTTTTT
```

```
DDDD   EEEEE  N   N  4  4    000
D   D  E      N   N  4  4   0   0
D   D  E      NN  N  4  4   0  00
D   D  EEEE   N N N  44444  0 0 0
D   D  E      N  NN     4   00  0
D   D  E      N   N     4   0   0
DDDD   EEEEE  N   N     4    000
```

```
HH        HH    000000      AAAAAA      GGGGGGGG
HH        HH    000000      AAAAAA      GGGGGGGG
HH        HH  OO      OO  AA      AA  GG
HH        HH  OO      OO  AA      AA  GG
HH        HH  OO      OO  AA      AA  GG
HH        HH  OO      OO  AA      AA  GG
HHHHHHHHHH    OO      OO  AA      AA  GG
HHHHHHHHHH    OO      OO  AA      AA  GG
HH        HH  OO      OO  AAAAAAAAAA  GG    GGGGGG
HH        HH  OO      OO  AAAAAAAAAA  GG    GGGGGG
HH        HH  OO      OO  AA      AA  GG        GG
HH        HH  OO      OO  AA      AA  GG        GG
HH        HH    000000    AA      AA    GGGGGG
HH        HH    000000    AA      AA    GGGGGG
```

```
          000000    UU      UU  TTTTTTTTTT      ;;;;        11
          000000    UU      UU  TTTTTTTTTT      ;;;;        11
        OO      OO  UU      UU      TT          ;;;;      1111
        OO      OO  UU      UU      TT          ;;;;      1111
        OO      OO  UU      UU      TT                      11
        OO      OO  UU      UU      TT                      11
        OO      OO  UU      UU      TT          ;;;;        11
        OO      OO  UU      UU      TT          ;;;;        11
        OO      OO  UU      UU      TT          ;;;;        11
        OO      OO  UU      UU      TT          ;;;;        11
....    OO      OO  UU      UU      TT            ;;        11
....    OO      OO  UU      UU      TT            ;;        11
....      000000    UUUUUUUUUU      TT          ;;      111111
....      000000    UUUUUUUUUU      TT          ;;      111111
```

File _1DIA1:[DEN40.SEDIMOD]HOAG.OUT;1 (8701,36,0), last revised on 7-OCT-1993 12:16, is a 37 block sequential file owned by UIC [DEN40]. The records are variable length with FORTRAN (FTN) carriage control. The longest record is 80 bytes.

Job HOAG (250) queued to CHI$PRINT on 8-OCT-1993 15:08 by user DEN40, UIC [DEN40], under account DEN40 at priority 100, started on printer LTA303 on 8-OCT-1993 15:08 from queue CHI$PRINT.


```
TTTTTTTTTT   9999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999     TTTTTTTTTT
TTTTTTTTTT   9999999999999999999999999  Digital Equipment Corporation - VAX/VMS Version V5.5-2  9999999999999999999999999     TTTTTTTTTT
TTTTTTTTTT   9999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999999     TTTTTTTTTT
```

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*****************************************************************
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      UNIVERSITY OF KENTUCKY COMPUTER MODEL
      OF SURFACE MINE HYDROLOGY AND SEDIMENTOLOGY
      FOR MORE INFORMATION CONTACT THE AGRICULTURAL
      ENGINEERING DEPARTMENT

      THE UK MODEL IS A DESIGN MODEL DEVELOPED TO PREDICT
      THE HYDRAULIC AND SEDIMENT RESPONSE FROM SURFACE
      MINED LANDS FOR A SPECIFIED RAINFALL EVENT (SINGLE STORM)

      VERSION DATE 9-23-83

      DISCLAIMER: NEITHER THE UNIVERSITY NOR ANY OF ITS EMPLOYEES
      ACCEPT ANY RESPONSIBILITY OR LEGAL LIABILITY FOR THE
      CONCLUSIONS DRAWN FROM THE RESULTS OF THIS MODEL

*****************************************************************
*****************************************************************


******************************************************************
*                                                                *
*     THE FOLLOWING VALUES ARE NOW PREDICTED BY SEDIMOT II.      *
*     THEY CAN BE FOUND IN SUMMARY TABLES.                       *
*      1. PERIOD OF SIGNIFICANT CONCENTRATION                    *
*      2. VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION       *
*         DURING PERIOD OF SIGNIFICANT CONCENTRATION             *
*      3. VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION       *
*         DURING PEAK 24 HOUR PERIOD                             *
*      4. ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING     *
*         PERIOD OF SIGNIFICANT CONCENTRATION                    *
*      5. ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION            *
*         DURING PEAK 24 HOUR PERIOD                             *
*                                                                *
*     ALL CONCENTRATIONS ARE IN ML/L.                            *
*                                                                *
******************************************************************


              ********************************************

                   WATERSHED IDENTIFICATION CODE
                   ------------------------------
                      HOAGLAND BAY SEDIMOT 2 ANALYSIS

              ********************************************
```

INPUT PARTICLE SIZE-PERCENT FINER DISTRIBUTIONS

```
SIZE,MM            4.800  2.000  0.410  0.170  0.074  0.037
                   0.025  0.013  0.010  0.007  0.003  0.002
                   0.001  0.000
```

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!  W A R N I N G  !!!!!!!!!!!!!!!!!!!!!!!!!!

LAST PERCENT FINER VALUE
IS NOT WITHIN THE EXPECTED LIMITS. THE
VALUE MUST BE NO SMALLER THAN  0.0000 AND IF POSSIBLE SHOULD NOT EXCEED
    0.000. SEDIMOT WILL CONTINUE WITH THE VALUE ENTERED,    0.0100 ,BUT IT
MAY CAUSE INACCURACIES OR EVEN TERMINATION LATER IN THE PROGRAM

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
```

```
PCT FINER NO. 1  100.000 98.000 94.000 60.000 30.000 17.000
                  12.000 10.000  9.000  7.000  6.000  4.000
                   0.100  0.010
```

```
!!!!!!!!!!!!!!!!!!!!!!!!!!!  W A R N I N G  !!!!!!!!!!!!!!!!!!!!!!!!!!

LAST PERCENT FINER VALUE
IS NOT WITHIN THE EXPECTED LIMITS. THE
VALUE MUST BE NO SMALLER THAN  0.0000 AND IF POSSIBLE SHOULD NOT EXCEED
    0.000. SEDIMOT WILL CONTINUE WITH THE VALUE ENTERED,    0.0100 ,BUT IT
MAY CAUSE INACCURACIES OR EVEN TERMINATION LATER IN THE PROGRAM

!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!!
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```
PCT FINER NO. 2  100.000 98.000 94.000 58.000 29.000 17.000
                  13.000  9.000  8.000  6.000  4.000  3.000
                   0.100  0.010
```

```
*********************INPUT VALUES*********************

STORM DURATION                   =      24.00   HOURS
PRECIPATION DEPTH                =       2.83   INCHES
SPECIFIC GRAVITY                 =       1.37
LOAD RATE EXPONENT FACTOR        =       1.50
SUBMERGED BULK SPECIFIC GRAVITY  =       1.25
```

* *

JUNCTION 1, BRANCH 1, STRUCTURE 1

* *

****

BETA IS NEGATIVE WHICH INHERENTLY INDICATES THAT THE STREAM SYSTEM TRANSPORT CAPACITY EXCEEDS THE SEDIMENT LOAD, AS EVALUATED BY WILLIAMS' TECHNIQUE. SEDIMOT II DOES NOT CONSIDER ERODIBLE CHANNELS SO BETA IS SET EQUAL TO .01. IF THE USER WISHES TO EVALUATE THE TRANSPORT CAPACITY OF THE STREAM DIRECTLY HE/SHE SHOULD USE SUBROUTINE SLOSS.

****

*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	4480.00	60.00	3.000	3.000	0.000	0.00	2.0
2	4480.00	60.00	3.000	3.000	0.000	0.00	2.0
3	4480.00	60.00	3.000	3.000	0.000	0.00	2.0
4	4480.00	60.00	3.000	3.000	0.000	0.00	2.0
5	4480.00	60.00	3.000	3.000	0.000	0.00	2.0

*** SEDIMENT INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	SEG NUM	SOIL K	LENGTH FEET	SLOPE PCT	CP VALUE	PART OPT	SURF COND
1	1	0.10	700.0	0.10	1.000	1.0	0.0
2	1	0.10	700.0	0.10	1.000	1.0	0.0
3	1	0.10	700.0	0.10	1.000	1.0	0.0
4	1	0.10	700.0	0.10	1.000	1.0	0.0
5	1	0.10	700.0	0.10	1.000	1.0	0.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)	SEDIMENT TONS	DIAM (MM)	DELIVERY RATIO 1	DELIVERY RATIO 2
1	138.09	0.27	275.49	0.030	0.287	0.995
2	138.09	0.27	275.49	0.030	0.287	0.995
3	138.09	0.27	275.49	0.030	0.287	0.995
4	138.09	0.27	275.49	0.030	0.287	0.995
5	138.09	0.27	275.49	0.030	0.287	0.995

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	512.2117	ACRE-FT
PEAK DISCHARGE	=	690.4578	CFS
AREA	=	22400.0000	ACRES

TIME OF PEAK DISCHARGE	=	14.70	HRS
BETA	=	0.0100	
RAINFALL EROSITIVITY FACTOR	=	46.36	EI UNIT
PEAK CONCENTRATION	=	2529.41	MG/L
PEAK SETTLEABLE CONCENTRATION	=	1.38	ML/L
PEAK SETTLEABLE CONCENTRATION	=	1725.64	MG/L
TOTAL SEDIMENT YIELD	=	1370.2817	TONS
REPRESENTATIVE PARTICLE SIZE	=	0.0299	MM
TIME OF PEAK CONCENTRATION	=	14.70	HRS
PERIOD OF SIGNIFICANT CONCENTRATION	=	24.70	HRS
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	1.07	ML/L
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	1.07	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	0.72	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	0.74	ML/L

* * * * * * * * * * * *

NULL STRUCTURE

* * * * * * * * * * * *

* *

JUNCTION 1, BRANCH 2, STRUCTURE 1

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BETA IS NEGATIVE WHICH INHERENTLY INDICATES THAT THE STREAM SYSTEM TRANSPORT CAPACITY EXCEEDS THE SEDIMENT LOAD, AS EVALUATED BY WILLIAMS' TECHNIQUE. SEDIMOT II DOES NOT CONSIDER ERODIBLE CHANNELS SO BETA IS SET EQUAL TO .01. IF THE USER WISHES TO EVALUATE THE TRANSPORT CAPACITY OF THE STREAM DIRECTLY HE/SHE SHOULD USE SUBROUTINE SLOSS.

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*** HYDRAULIC INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	AREA ACRES	CURVE NUMBER	TC HR	TT HR	ROUTING COEFFICIENTS K-HRS	X	UNIT HYDRO
1	4480.00	60.00	3.000	3.000	0.000	0.00	2.0
2	4480.00	60.00	3.000	3.000	0.000	0.00	2.0
3	4480.00	60.00	3.000	3.000	0.000	0.00	2.0
4	4480.00	60.00	3.000	3.000	0.000	0.00	2.0
5	4480.00	60.00	3.000	3.000	0.000	0.00	2.0

*** SEDIMENT INPUT VALUES FOR SUBWATERSHEDS ***

WATER SHED	SEG NUM	SOIL K	LENGTH FEET	SLOPE PCT	CP VALUE	PART OPT	SURF COND
1	1	0.10	700.0	0.10	1.000	2.0	0.0
2	1	0.10	700.0	0.10	1.000	2.0	0.0
3	1	0.10	700.0	0.10	1.000	2.0	0.0
4	1	0.10	700.0	0.10	1.000	2.0	0.0
5	1	0.10	700.0	0.10	1.000	2.0	0.0

* * * COMPUTED VALUES FOR INDIVIDUAL WATERSHEDS * * *

WATERSHED	PEAK FLOW (CFS)	RUNOFF (INCHES)	SEDIMENT TONS	DIAM (MM)	DELIVERY RATIO 1	DELIVERY RATIO 2
1	138.09	0.27	275.49	0.029	0.287	0.995
2	138.09	0.27	275.49	0.029	0.287	0.995
3	138.09	0.27	275.49	0.029	0.287	0.995
4	138.09	0.27	275.49	0.029	0.287	0.995
5	138.09	0.27	275.49	0.029	0.287	0.995

NOTE: SEDIMENT DOES NOT INCLUDE POSSIBLE DEPOSITION BY DELIVERY RATIO 2

***** SUMMARY TABLE FOR TOTAL WATERSHED *****

RUNOFF VOLUME	=	512.2117	ACRE-FT
PEAK DISCHARGE	=	690.4578	CFS
AREA	=	22400.0000	ACRES

TIME OF PEAK DISCHARGE	=	14.70	HRS
BETA	=	0.0100	
RAINFALL EROSITIVITY FACTOR	=	46.36	EI UNIT
PEAK CONCENTRATION	=	2529.74	MG/L
PEAK SETTLEABLE CONCENTRATION	=	1.45	ML/L
PEAK SETTLEABLE CONCENTRATION	=	1814.73	MG/L
TOTAL SEDIMENT YIELD	=	1370.4640	TONS
REPRESENTATIVE PARTICLE SIZE	=	0.0284	MM
TIME OF PEAK CONCENTRATION	=	14.70	HRS
PERIOD OF SIGNIFICANT CONCENTRATION	=	24.70	HRS
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	1.13	ML/L
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	1.13	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	0.76	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	0.78	ML/L

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NULL STRUCTURE

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JUNCTION 2, BRANCH 1, STRUCTURE 1

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ZERO SUBWATERSHEDS ABOVE STRUCTURE

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**** SUMMARY TABLE OF STRUCTURE INPUT VALUES *****

TOTAL SEDIMENT YIELD	=	2740.7458	TONS
TOTAL RUNOFF VOLUME	=	1024.4233	AC-FT
PEAK RUNOFF DISCHARGE	=	1380.12	CFS
TOTAL DRAINAGE AREA	=	44800.00	ACRES
PEAK CONCENTRATION	=	2529.58	MG/L
PEAK SETTLEABLE CONCENTRATION	=	1.42	ML/L
PEAK SETTLEABLE CONCENTRATION	=	1770.12	MG/L
PERIOD OF SIGNIFICANT CONCENTRATION	=	24.60	HRS
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	1.10	ML/L
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	1.10	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	0.74	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	0.76	ML/L

* *

POND RESULTS

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***** CONTROL VARIABLES OPTIONS *****

FLOW	FRACTN	ISDO	NRHP	NSP	NCSTR
1	0	1	500	9	2

***** BASIN GEOMETRY *****

STAGE (FT)	AREA (ACRES)	AVERAGE DEPTH (FT)	DISCHARGE (CFS)	CAPACITY (ACRES-FT)
0.00	0.000	0.00	0.00	0.00
2.00	3.840	1.00	0.00	3.84
4.00	7.960	2.47	0.00	15.64
6.00	8.550	4.16	0.00	32.15
8.00	9.130	5.96	0.00	49.83
10.00	9.630	7.78	0.00	68.59
12.00	10.100	9.59	4690.00	88.32
14.00	10.570	11.39	7490.00	108.99
15.50	10.870	12.73	9535.00	125.07

***** STORM EVENT SUMMARY *****

TURBULENCE FACTOR	=	1.50	
PERMANENT POOL CAPACITY	=	68.590	ACRE-FT
DEAD STORAGE	=	0.00	PERCENT
TIME INCREMENT OUTFLOW	=	0.10	HRS
VISCOSITY	=	0.009	CM**2/SEC
INFLOW RUNOFF VOLUME	=	1024.423	ACRE-FT
OUTFLOW ROUTED VOLUME	=	1024.422	ACRE-FT
STORM VOLUME DISCHARGED (PLUG FLOW)	=	1024.422	ACRE-FT
POND VOLUME AT PEAK STAGE	=	74.390	ACRE-FT
PEAK STAGE	=	10.588	FT
PEAK INFLOW RATE	=	1380.125	CFS
PEAK DISCHARGE RATE	=	1378.680	CFS
PEAK INFLOW SEDIMENT CONCENTRATION	=	2529.58	MG/L
PEAK EFFLUENT SEDIMENT CONCENTRATION	=	2035.84	MG/L
PEAK EFFLUENT SETTLEABLE CONCENTRATION	=	0.9662	ML/L
PEAK EFFLUENT SETTLEABLE CONCENTRATION	=	1207.70	MG/L
STORM AVERAGE EFFLUENT CONCENTRATION	=	1440.14	MG/L
AVERAGE EFFLUENT SEDIMENT CONCENTRATION	=	1440.14	MG/L
BASIN TRAP EFFICIENCY	=	26.96	PERCENT
DETENTION TIME OF FLOW WITH SEDIMENT	=	0.05	HRS
DETENTION TIME FROM HYDROGRAPH CENTERS	=	0.05	HRS
DETENTION TIME INCLUDING STORED FLOW	=	0.05	HRS
SEDIMENT LOAD DISCHARGED	=	2001.75	TONS
PERIOD OF SIGNIFICANT CONCENTRATION	=	24.70	HRS
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	0.68	ML/L
VOLUME WEIGHTED AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	0.69	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PERIOD OF SIGNIFICANT CONCENTRATION	=	0.47	ML/L
ARITHMETIC AVERAGE SETTLEABLE CONCENTRATION DURING PEAK 24 HOUR PERIOD	=	0.49	ML/L

*** RUN COMPLETED ****

APPENDIX E

DREDGING COMPUTATIONS, DREDGING AND POTENTIAL DISPOSAL SITE LOCATION MAP FOR LAKE SHAFER (1993)

Aug/93

Survey on Lake Shafer: Dredging-Cross section data for each transect

transect # — first row distance from shore in feet; second row depth to be dredged in feet

Lake Shafer- Distance from Eastern Shore

transect #										Water Surface elevation
23	0.0	10.0	126.3	242.6	358.9	475.2	591.5	707.8	717.8	648.46
	0.0	0.0	0.0	0.0	0.0	2.0	1.0	4.0	0.0	
24	0.0	10.0	123.5	237.0	350.5	464.0	577.5	691.0	701.0	648.56
	0.0	0.0	0.0	0.0	2.0	0.0	0.0	4.0	0.0	
25	0.0	10.0	142.0	274.0	406.0	538.0	670.0	804.0	814.0	648.45
	0.0	4.0	3.0	1.0	0.0	0.0	0.0	0.0	0.0	
26	0.0	10.0	140.5	271.0	401.5	532.0	662.5	793.0	803.0	648.4
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
27	0.0	10.0	171.7	333.4	495.0	656.8	818.5	980.0	990.0	
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
28	0.0	10.0	196.4	382.8	569.2	755.6	942.0	1128.5	1138.5	648.65
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
29	0.0	10.0	166.2	322.4	478.6	634.8	791.0	947.0	957.0	648.7
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
30	0.0	10.0	167.1	324.2	481.3	638.4	795.5	952.5	962.5	648.84
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
31	0.0	10.0	258.8	507.6	756.4	1005.2	1254.0	1502.5	1512.5	648.89
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
32	0.0	10.0	154.5	299.0	443.5	588.0	732.5	742.5		649.73
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
33	0.0	10.0	319.8	629.6	929.4	1249.5	1259.5			649.23
	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
37	0.0	10.0	236.8	463.6	690.4	917.2	1134.0	1144.0		649.3
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
38	0.0	10.0	263.0	516.0	769.0	1022.0	1275.0	1530.0	1540.0	649.38
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	

39	0.0	10.0	280.0	550.0	820.0	1090.0	1100.0			649.41
	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
40	0.0	10.0	223.8	437.6	651.4	865.2	1079.0	1089.0		649.45
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
41	0.0	10.0	182.7	355.4	528.1	700.8	873.5	1046.0	1056.0	648.96
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0	
45	0.0	10.0	227.8	445.6	663.4	881.0	891.0			649.55
	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
46	0.0	10.0	267.8	525.6	783.4	1041.2	1299.0	1309.0		649.55
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
47	0.0	10.0	187.5	365.0	542.5	720.0	897.5	907.5		649.64
	0.0	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

Tippicanoe River - Distance from Eastern Shore

1	0.0	10.0	82.0	154.0	226.0	236.0		648.51
	0.0	3.5	2.2	0.0	2.2	0.0		
2	0.0	10.0	96.8	183.7	270.5	280.5		
	0.0	3.5	0.0	0.0	1.9	0.0		
3	0.0	10.0	115.0	220.0	325.0	430.0	440.0	648.29
	0.0	2.0	0.5	1.5	0.0	2.0	0.0	
4	0.0	5.0	55.0	105.0	110.0			648.62
	0.0	3.0	0.0	3.0	0.0			
5	0.0	10.0	117.0	224.0	331.0	341.0		
	0.0	0.0	0.0	0.0	0.0	0.0		
6	0.0	10.0	85.6	161.2	246.9	302.5	312.5	
	0.0	1.5	1.0	0.0	0.0	1.0	0.0	
7	0.0	10.0	90.3	170.6	250.9	331.0	341.0	
	0.0	2.0	0.0	0.0	2.0	3.0	0.0	
8	0.0	10.0	156.3	302.6	448.9	595.0	605.0	648.64
	0.0	0.0	0.0	0.0	0.0	4.2	0.0	
9	0.0	10.0	94.4	178.8	263.2	347.0	357.5	648.44

	0.0	2.5	0.0	0.0	0.0	3.5	0.0		
10	0.0	10.0	105.2	200.4	295.6	390.8	400.8		
	0.0	4.0	3.0	4.5	0.0	0.0	0.0		
12	0.0	10.0	149.0	288.0	427.0	566.0	705.0	715.0	
	0.0	3.5	2.0	0.0	0.0	0.0	0.0	0.0	
13	0.0	10.0	163.1	316.2	469.3	622.5	632.5		
	0.0	0.0	0.0	0.5	4.5	1.5	0.0		
14	0.0	10.0	137.0	264.0	391.0	518.0	528.0		
	0.0	3.0	0.0	2.0	2.5	4.5	0.0		
15	0.0	10.0	158.0	307.6	456.4	595.0	605.0		
	0.0	3.0	0.0	2.0	2.7	3.0	0.0		
16	0.0	10.0	170.0	330.0	490.0	650.0	660.0		
	0.0	0.0	0.0	3.0	0.0	0.0	0.0		
18	0.0	10.0	170.0	330.0	490.0	650.0	660.0		648.25
	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
19	0.0	10.0	149.4	288.8	428.2	567.5	577.5		648.24
	0.0	3.0	0.0	0.0	0.0	0.0	0.0		
20	0.0	10.0	142.5	275.0	407.5	540.0	550.0		648.29
	0.0	0.0	0.0	0.0	0.0	0.0	0.0		
22	0.0	10.0	128.7	247.4	366.1	485.0	495.0		648.35
	0.0	0.0	0.0	0.0	0.0	0.0	0.0		

Honey Creek Bay - Distance from Southern Shore

42	0.0	10.0	110.0	210.0	310.0	409.8	419.8
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
43	0.0	10.0	128.8	247.6	366.4	485.0	495.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0
44	0.0	10.0	225.0	440.0	655.0	870.0	880.0
	0.0	1.0	1.5	0.0	0.0	2.0	0.0

Keans Bay - Distance from Southern Shore

34	0.0	10.0	87.5	165.0	242.5	320.0	330.0
	0.0	0.0	0.0	0.0	0.0	0.0	0.0

35	0.0	10.0	149.4	288.8	428.2	567.5	577.5			
	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
36	0.0	10.0	110.0	210.0	310.0	413.5	423.5			
	0.0	3.5	0.5	0.0	0.0	2.0	0.0			
	Hogland Bay - Distance from Southern Shore									
48	0.0	10.0	112.5	215.0	317.5	420.0	430.0			
	0.0	1.0	0.0	0.0	0.0	0.0	0.0			
66	0.0	10.0	73.8	137.6	201.4	265.0	275.0			
	0.0	1.0	0.9	3.0	4.0	4.5	0.0			
	Big Monon Bay (Creek) - Distance from Northern Shore									
49	0.0	10.0	160.4	310.8	461.2	611.5	621.5			648.57
	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
50	0.0	10.0	128.8	247.6	366.4	485.0	495.0			
	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
51	0.0	10.0	170.0	330.0	490.0	650.0	660.0			
	0.0	0.0	0.0	0.0	0.0	0.0	0.0			
53	0.0	10.0	223.3	436.6	650.0	660.0				648.95
	0.0	0.0	0.0	0.0	0.0	0.0				
54	0.0	10.0	226.7	443.4	660.1	876.8	1093.5	1310.0	1320.0	
	0.0	0.0	0.0	0.0	0.0	0.0	1.0	1.0	0.0	
56	0.0	10.0	94.4	178.8	263.1	347.5	357.5			648.95
	0.0	3.0	0.0	0.0	0.0	4.0	0.0			
59	0.0	10.0	138.4	266.8	395.1	523.5	533.5			
	0.0	4.0	0.0	0.0	0.0	4.0	0.0			
60	0.0	10.0	87.5	165.0	242.5	320.0	330.0			
	0.0	2.0	0.0	0.0	0.0	2.0	0.0			
60A	0.0	10.0	163.1	316.3	469.4	622.5	632.5			
	0.0	3.0	2.5	0.0	0.0	1.0	0.0			
61	0.0	10.0	163.1	316.3	469.4	622.5	632.5			648.96
	0.0	4.0	1.0	2.5	0.0	4.0	0.0			

62	0.0	10.0	105.4	200.8	296.1	391.5	401.5
	0.0	4.0	0.0	0.0	0.0	4.0	0.0
64	0.0	10.0	73.8	137.5	201.3	265.0	275.0
	0.0	2.5	0.0	0.0	0.0	0.0	0.0
65	0.0	10.0	80.0	150.0	220.0	290.0	300.0
	0.0	2.5	1.9	0.0	1.5	3.0	0.0
63	0.0	10.0	105.0	200.0	295.0	390.0	400.0
	0.0	4.5	1.0	1.0	1.0	4.5	0.0

Dredging calculation for Lake Shafer and it's tributaries

Transect	Area(sq.ft.)	Lake Shafer Area(acre	Distance(ft)	Volume(cu.ft.)	Volume(acre-ft)
23	601.5	0.014			
			726.0	390406.5	9.0
24	474	0.011			
			924.0	594132.0	13.6
25	812	0.019			
			1507.0	611842.0	14.0
26	0	0.000			
			935.0	0.0	0.0
27	0	0.000			
			1567.5	0.0	0.0
28	0	0.000			
			1127.5	0.0	0.0
29	0	0.000			
			1650.0	0.0	0.0
30	0	0.000			
			770.0	0.0	0.0
31	0	0.000			
			1721.5	0.0	0.0
32	0	0.000			
			2777.5	0.0	0.0
33	0	0.000			
			1688.5	0.0	0.0
37	0	0.000			
			2035.0	0.0	0.0
38	0	0.000			
			2200.0	0.0	0.0
39	0	0.000			
			863.5	0.0	0.0
40	0	0.000			
			1336.5	0.0	0.0
41	0	0.000			
			1045.0	0.0	0.0
45	0	0.000			
			1155.0	0.0	0.0
46	0	0.000			
			1100.0	0.0	0.0
47	0	0.000			
			SUM =	**1596380.5**	**36.6**

Tippicanoe River

Transect	Area(sq.ft.)	Area(acre	Distance(ft)	Volume(cu.ft.)	Volume(acre-ft)
1	392.1	0.009			
			385.0	125798.8	2.9
2	261.4	0.006			
			1595.0	559366.5	12.8
3	440.0	0.010			
			984.5	216590.0	5.0
5	0.0	0.000			
			291.5	25156.5	0.6
6	172.6	0.004			
			2711.5	757186.4	17.4
7	385.9	0.009			
			1017.5	363094.9	8.3
8	327.8	0.008			
			621.5	189806.1	4.4
9	283.0	0.006			
			968.0	584381.6	13.4
10	924.4	0.021			
			1127.5	824879.0	18.9
12	538.8	0.012			
			676.5	482648.9	11.1
13	888.1	0.020			
			1138.5	1123358.0	25.8
14	1085.3	0.025			
			946.0	1055546.8	24.2
15	1146.3	0.026			
			1292.5	1050996.4	24.1
16	480.0	0.011			
			1457.5	349800.0	8.0
18	0.0	0.000			
			550.0	61627.5	1.4
19	224.1	0.005			
			1617.0	181184.9	4.2
20	0.0	0.000			
			869.0	0.0	0.0
22	0.0	0.000			
			SUM =	**7951422.1**	**182.5**

Keans Bay

Transec	Area(sq.ft.)	Area(acre	Distance(ft)	Volume(cu.ft.)	Volume(acre-ft)
34	0.0	0.000			
			896.5	0.0	0.0

Transec	Area(sq.ft.)	Area(acre	Distance(ft)	Volume(cu.ft.)	Volume(acre-ft)
35	0.0	0.000			
			1006.5	179157.0	4.1
36	356.0	0.008			
			SUM =	**179157.0**	**4.1**

Honey Creek Bay

Transec	Area(sq.ft.)	Area(acre	Distance(ft)	Volume(cu.ft.)	Volume(acre-ft)
42	0.0	0.000			
			907.5	0.0	0.0
43	0.0	0.000			
			935.0	308550.0	7.1
44	660.0	0.015			
			SUM =	**308550.0**	**7.1**

Big Monon Bay

Transec	Area(sq.ft.)	Area(acre	Distance(ft)	Volume(cu.ft.)	Volume(acre-ft)
49	0.0	0.000			
			715.0	0.0	0.0
50	0.0	0.000			
			605.0	0.0	0.0
51	0.0	0.000			
			924.0	0.0	0.0
53	0.0	0.000			
			852.5	140619.9	3.2
54	329.9	0.008			
			1980.0	653697.0	15.0
56	330.4	0.008			
			1540.0	680680.0	15.6
59	553.6	0.013			
			1721.5	627142.5	14.4
60	175.0	0.004			
			1529.0	680557.9	15.6
60A	715.2	0.016			
			852.5	811409.5	18.6
61	1188.4	0.027			
			357.5	287787.5	6.6
62	421.6	0.010			
			770.0	197851.5	4.5
64	92.3	0.002			
			0	0.0	0.0
65	458	0.011			
			600	364650.0	8.4
63	757.5	0.017			
			SUM =	**4444395.7**	**102.0**

The volume of sediments to be dredged
from Lake Shafer and it's tributaries is 332.4 acre-ft

LIST OF DREDGING CONTRACTORS

1. Liquid Waste Technology, Inc.
   422 Main Street
   P.B. 250
   Somerset, WI 54025

   Phone: (715) 247-5464

2. Carylon Corp.
   2500 W. Arthington Street
   Chicago, IL 60612

   Phone: (312) 666-7700

3. Environmental Contracting
   4190 W. 123rd Street
   Alsip, IL 60658

   Phone: 1-800-331-1945
   (708) 389-4311

4. Andrie Corporation
   561 East Western Avenue
   P.B. 1548
   Muskegon, MI 49443

   Phone: (616) 228-2226

5. George Gradel Company
   P.B. 8337 Station A
   Toledo, OH 43605-0337

6. Holloway Construction Company
   29250 Wixom Road
   Wixon, MI 48096-9630

7. Brand Utility Services - Underwater Construction
   740 W. Western Avenue
   Muskegon, MI 49440

   Phone: (616) 726-4016

8. Lake Michigan Contractors
216 Van Raalte
Holland, MI 49423

Phone: (616) 392-2958

9. Southwind Construction Corp.
14649 Highway 41
N. Evansville, IN 47711

10. Tennant's Industrial Dredging, Inc.
3130 N. 21st
Terra Haute, IN 47804

11. Wintergreen, Inc.
P.B. 328
Muskegon, MI 49443-0328

12. C and C Dredging & Construction
P.B. 501
Lake Zurich, IL 60047

Phone: (708) 438-9153

13. Koester Equipment, Inc.
14649 Highway 41 North
Evansville, IN 47711

Phone: (812) 867-7220

APPENDIX F

MAP SHOWING LOCATIONS OF PROPOSED SEDIMENT TRAPS

APPENDIX G

BRIEF DESCRIPTION ON DREDGING METHODS AND DISPOSAL ALTERNATIVES

DREDGING METHODS

Two basic types of dredges are the bucket and the hydraulic. Bucket dredges are sometimes referred to as mechanical dredges, and are classified as grab, dipper and ladder. Hydraulic dredges are plain-suction, draghead and cutterhead.

A. Bucket Dredges:

All bucket dredges have one (1) limitation. The discharge must be along side the place of excavation, or when the spoil cannot be placed along side, scows or barges must be used to carry it away. This type of dredge is not practical for large quantity or widely dispersed excavating.

1. Grab Dredges

Grab dredge is essentially a grab bucket operated from a derrick mounted on a flat-topped barge (figs. A & B). This dredge works well in silts and stiff muds and is particularly effective where there are obstructions and trash. In hard materials its production is poor, and in stiff and hard clays it is unsuitable. This can be used up to 100.0 feet deep. The deeper the dredging, the less the production, because of the increased hoisting time. It has less penetrating power in hard materials and leaves an irregular bottom. The two (2) general types of buckets used are the clamshell for mud or stiff mud and the orange peel for loose rock or other hard or bulky materials.

A large grab dredge with a one cubic yard bucket may raise 45 to 55 cubic yards of mud per hour when working in 15.0 to 20.0 feet of water. In clay about half this production can be obtained.

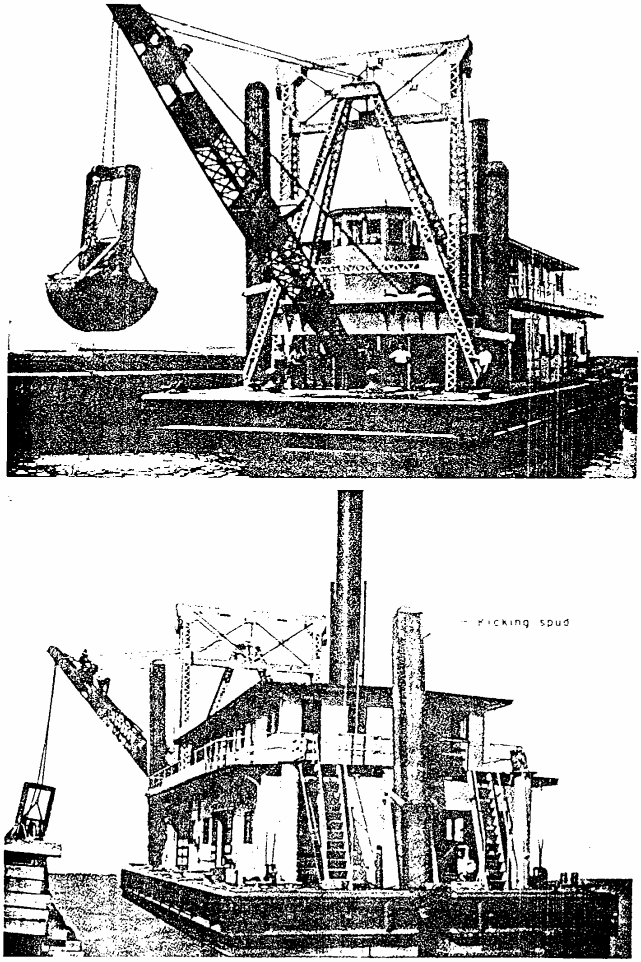

Figure A & B: Five-cubic-yard Grab Dredge
(A, Top) Bow View;
(B, Bottom) Stern View.
(Ellicott Machine Corp.)

2. Dipper Dredges

The dipper dredge is a power shovel operating from a barge (see fig. C). It is most effective in hard materials such as till, soft and broken-up rock, and shales. It works well where there are obstructions such as boulders, snags or timbers. Maximum digging depth of about 65.0 feet. With a one-cubic yard bucket in muds 50.0 to 250.0 cubic yards can be dredged per hour. In clay about half this is possible.

3. Ladder Dredges

The ladder dredge is probably the oldest of the dredges. These dredges do their excavating with a continuous chain of buckets which are supported on an inclinable ladder and move up and down around two (2) pivots called tumblers.

Single Ladder dredges have the ladder collinear with the center line of the hull - double ladder dredges have the ladders set on either side of the center line. Double ladder dredges are practically obsolete. The single-ladder dredge is used in the United States in the production of gold, and in some instances sand and gravel. Where traffic is limited and where there are rocks, piling and other such obstructions single ladder dredge is highly practical. In areas where pump-ashore methods cannot be used or where floatation is a problem it is quite economical.

The size of the bucket and the speed of the bucket cycle are dependent upon the materials being dredged. Small buckets are preferred for rock and other hard materials; large buckets are generally used for soft digging. Bucket sizes vary between 5.0 and 55.0 cubic feet. Bucket cycle may average from 12.0 to 30.0 buckets per minute. Maximum digging depth for most of these dredges is around 40.0 feet, but 75.0 feet is not uncommon.

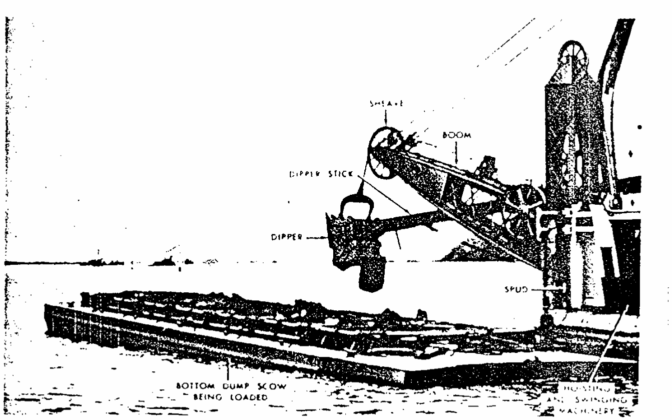

Figure C: Dipper Dredge.

Generally, the ladder dredge has low efficiency compared with other types of dredges. Costs for dredging with this dredge are about twice that of grab dredging.

B. Hydraulic Dredges

Hydraulic dredges have a centrifugal pump discharging either into the hold of the dredge itself, into barges along side or ashore. They also have a suction line through which the pump is supplied with material. Depending upon the means of loosening and picking up the material they are divided into three (3) types; (1) plain-suction dredges, (2) draghead dredges and (3) cutter head.

(1) Plain-Suction Dredges

Plain-suction dredges are similar in hull construction to a regular ship, but they often differ from other dredges in the location of the suction pipe. The plain suction dredge has its pipe in a well at the bow, where as other types, such as the hopper drags, have their suction pipes along side. The modern plain-suction dredge has jets installed to force high pressure water to break up the material. Plain-suction dredges operate best when they are able to remain stationary and can dredge a hole into which the surrounding sand can run. They are not very effective in hard materials.

(2) Draghead Dredges

The plain-suction dredge often uses a special suction head called a dust pan or draghead attached to the end of the suction (fig. D). Dredges using these attachments are generally hopper dredges, but occasionally they pump into barges tied along side, or have side casting booms (fig. E).

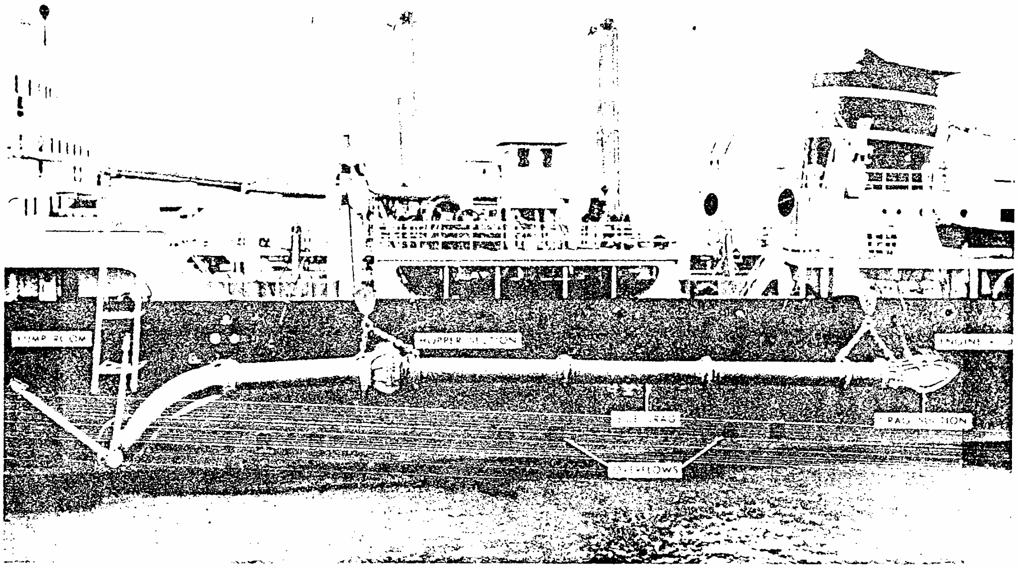

Figure D: Suction and Draghead on Hopper Dredge.

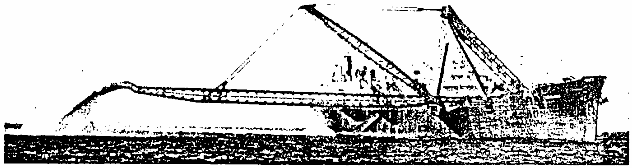

Figure E: Converted T-2 Tanker. Two 24-inch discharges extend 290 feet outward. (National Bulk Carriers, Inc.)

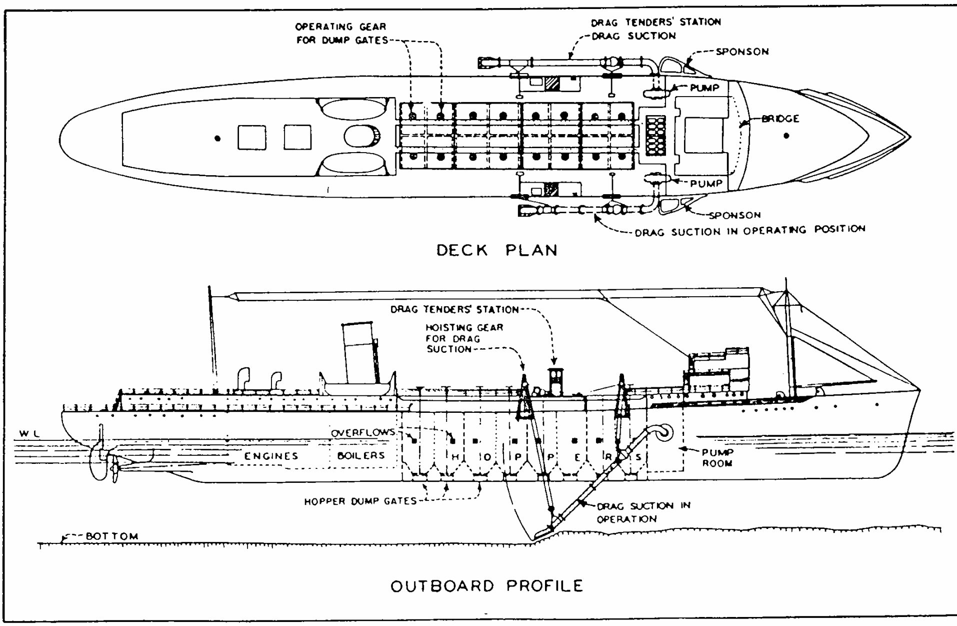

Figure F: Typical Hopper Dredge.

The draghead dredge requires the drag to be in contact with the bottom and the dredge in motion while dredging. It usually has moulded hull and is self propelled (fig. F). Built-in hopper capacities vary between 500.0 and 8,000.0 cubic yards. When the hoppers dredges are full the dredge stops dredging and transports the material to a disposal areas. This is the main disadvantage of the hopper dredge. It has to stop dredging to transport the material.

(3) Cutterhead

Cutterhead is the most versatile and popular dredge in the world today. Essentially, a combination of all other dredges, its prime function is to excavate and move material hydraulically to some other location without rehandling. It is generally referred to by the size of its floating discharge line; for example, a 24.0 inch dredge.

Figure G shows the dredge components and their location on the dredge. The dredge with its pipe and all supporting equipment like derrick, tenders (tugs), fuel and pipe barges, and surveying craft is referred to as the plant.

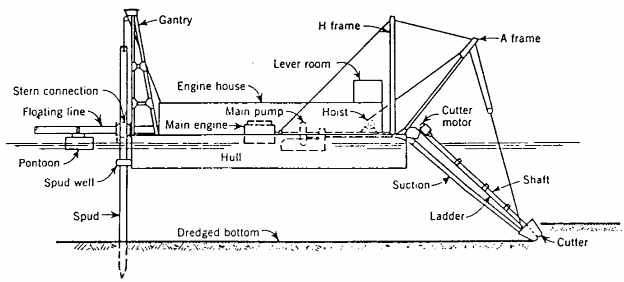

Figure G: Dredge Components.

DISPOSAL ALTERNATIVES

Major disposal alternatives are open water, confined, open water with restrictions and confined disposal with restrictions. Disposal alternatives with restrictions are used whenever results of the testing protocols indicate that they are needed.

Open Water Disposal

Open water disposal involves placing dredged material in open water sites by direct pipeline discharge, hopper dredge discharge, or dumping from scows. For conventional open-water disposal, no special placement techniques are used and the material is normally discharged at a selected point within a designated disposal site. The capacity of open water disposal site is determined by the volume of accumulated material that can be placed without exceeding the designated site boundaries or exceeding water depth constrains. If the sediment is contaminated the techniques to be followed include use of subaqueous discharge points, diffusers, subaqueous containment of material or capping of contaminated material with clean material.

Confined Disposal

Conventional upland disposal consists of placing or pumping the dredged material into a diked containment area where the material settles and consolidates. The area should be designed to provide good sedimentation and sufficient volume for storage. The supernatant water can be discharged over a weir which is designed to maintain good effluent quality by minimizing resuspension of settled material.

Following the completion of the disposal operation, the site should be managed to promote consolidation and drying. The containment area can then be used for additional disposal, mined for productive use of the material or returned to the sponsor for other uses.

For contaminated sediments, the dredged material and associated contaminants should be contained within the disposal site. Dredged material is to be modified physically, chemically, or biologically to reduce toxicity, mobility, etc. Dredged material is to be held for a temporary period at the site and later removed to another site for ultimate disposal. Dredged material can be classified and reclaimed material can be used for beneficial purposes.

<u>APPENDIX H</u>

REPORTED CHEMICAL TEST RESULTS

NET® NATIONAL ENVIRONMENTAL TESTING, INC.

NET Midwest, Inc.
Indianapolis Division
6964 Hillsdale Court
Indianapolis, IN 46250
Tel: (317) 842-4261
Fax: (317) 842-4286

ANALYTICAL REPORT

Mr. John Lardner
WEHRAN ENGINEERING
7205 Shadeland Station
Suite 120
Indianapolis, IN 46256

05-14-91

Sample No.: 36919

P.O. NO.: 44469

Page 1

Sample Description: SITE 1 LOWE'S BRIDGE

Date Taken: 04-04-91

Date Received: 04-05-91

Parameters	Results	Units
COD	45000.	ug/g
Cyanide, Total	<0.25	ug/g
Nitrogen, Ammonia	31.	ug/g
Oil & Grease, Soxhlet	220.	ug/g
Phenol	<0.125	ug/g
Solids, Total	41.	%
Arsenic, Total	21.	ug/g
Cadmium, Total	0.95	ug/g
Chromium, Total	4.3	ug/g
Lead, Total	4.6	ug/g
Mercury, Total	<0.02	ug/g
Selenium, Total	<2.	ug/g
Silver, Total	<0.5	ug/g

RECEIVED
MAY 15 1991

Steve Johnson
Steve Johnson
Project Manager

NET
NATIONAL ENVIRONMENTAL TESTING, INC.

NET Midwest, Inc.
Indianapolis Division
6964 Hillsdale Court
Indianapolis, IN 46250
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ANALYTICAL REPORT

Mr. John Lardner
WEHRAN ENGINEERING
7205 Shadeland Station
Suite 120
Indianapolis, IN 46256

05-14-91

Sample No.: 36919

P.O. NO.: 44469

Sample Description: SITE 1 LOWE'S BRIDGE

Date Taken: 04-04-91

Date Received: 04-05-91

Parameters	Results	Units
PESTICIDES/PCB		
PCB-1016	<1.0	ug/g
PCB-1221	<1.0	ug/g
PCB-1232	<1.0	ug/g
PCB-1242	<1.0	ug/g
PCB-1248	<1.0	ug/g
PCB-1254	<1.0	ug/g
PCB-1260	<1.0	ug/g
Aldrin	<0.5	ug/g
Chlordane	<5.0	ug/g
Dieldrin	<0.5	ug/g
4,4'-DDD	<0.5	ug/g
4,4'-DDE	<0.5	ug/g
4,4'-DDT	<0.5	ug/g
Alpha-endosulfan	<0.5	ug/g
Beta-endosulfan	<0.5	ug/g
Endosulfan sulfate	<0.5	ug/g
Endrin	<0.5	ug/g
Endrin aldehyde	<0.5	ug/g
Heptachlor	<0.5	ug/g
Heptachlor epoxide	<0.5	ug/g
Alpha-BHC	<0.5	ug/g
Beta -BHC	<0.5	ug/g
Gamma - BHC (Lindane)	<0.5	ug/g
Delta - BHC	<0.5	ug/g
Methoxychlor	<0.5	ug/g
Toxaphene	<10.	ug/g
SURROGATE RECOVERY	c	
Dibutylchlorendate	**	%

Steve Johnson
Steve Johnson
Project Manager

NET
NATIONAL ENVIRONMENTAL TESTING, INC.®

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Indianapolis Division
6964 Hillsdale Court
Indianapolis, IN 46250
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ANALYTICAL REPORT

Mr. John Larden
WEHRAN ENGINEERING
7205 Shadeland Station
Suite 120
Indianapolis, IN 46256

05-14-91

Sample No.: 36920

P.O. NO.: 44469

Page 3

Sample Description: SITE 3 WESTERN SAND BAR AT TIMMONS

Date Taken: 04-04-91

Date Received: 04-05-91

Parameters	Results	Units
COD	5600.	ug/g
Cyanide, Total	<0.25	ug/g
Nitrogen, Ammonia	4.1	ug/g
Oil & Grease, Soxhlet	150.	ug/g
Phenol	<0.125	ug/g
Solids, Total	78.	%
Arsenic, Total	12.	ug/g
Cadmium, Total	<0.50	ug/g
Chromium, Total	2.2	ug/g
Lead, Total	<2.5	ug/g
Mercury, Total	<0.02	ug/g
Selenium, Total	<2.	ug/g
Silver, Total	<0.5	ug/g

Steve Johnson

Steve Johnson
Project Manager

NET ®

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ANALYTICAL REPORT

Mr. John Larden
WEHRAN ENGINEERING
7205 Shadeland Station
Suite 120
Indianapolis, IN 46256

05-14-91

Sample No.: 36920

P.O. NO.: 44469

Sample Description: SITE 3 WESTERN SAND BAR AT TIMMONS

Date Taken: 04-04-91 Date Received: 04-05-91

Parameters	Results	Units
PESTICIDES/PCB		
PCB-1016	<1.0	ug/g
PCB-1221	<1.0	ug/g
PCB-1232	<1.0	ug/g
PCB-1242	<1.0	ug/g
PCB-1248	<1.0	ug/g
PCB-1254	<1.0	ug/g
PCB-1260	<1.0	ug/g
Aldrin	<0.25	ug/g
Chlordane	<2.5	ug/g
Dieldrin	<0.25	ug/g
4,4'-DDD	<0.25	ug/g
4,4'-DDE	<0.25	ug/g
4,4'-DDT	<0.25	ug/g
Alpha-endosulfan	<0.25	ug/g
Beta-endosulfan	<0.25	ug/g
Endosulfan sulfate	<0.25	ug/g
Endrin	<0.25	ug/g
Endrin aldehyde	<0.25	ug/g
Heptachlor	<0.25	ug/g
Heptachlor epoxide	<0.25	ug/g
Alpha-BHC	<0.25	ug/g
Beta -BHC	<0.25	ug/g
Gamma - BHC (Lindane)	<0.25	ug/g
Delta - BHC	<0.25	ug/g
Methoxychlor	<0.25	ug/g
Toxaphene	<5.0	ug/g
SURROGATE RECOVERY	c	
Dibutylchlorendate	**	%

Steve Johnson

Steve Johnson
Project Manager

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ANALYTICAL REPORT

Mr. John Larden
WEHRAN ENGINEERING
7205 Shadeland Station
Suite 120
Indianapolis, IN 46256

05-14-91

Sample No.: 36921

P.O. NO.: 44469

Page 5

Sample Description: SITE 5 SANDBAR

Date Taken: 04-04-91

Date Received: 04-05-91

Parameters	Results	Units
COD	14000.	ug/g
Cyanide, Total	<0.25	ug/g
Nitrogen, Ammonia	35.	ug/g
Oil & Grease, Soxhlet	93.	ug/g
Phenol	<0.125	ug/g
Solids, Total	73.	%
Arsenic, Total	13.	ug/g
Cadmium, Total	<0.50	ug/g
Chromium, Total	<2.0	ug/g
Lead, Total	<2.5	ug/g
Mercury, Total	<0.02	ug/g
Selenium, Total	<2.	ug/g
Silver, Total	<0.5	ug/g

Steve Johnson

Steve Johnson
Project Manager

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7205 Shadeland Station
Suite 120
Indianapolis, IN 46256

05-14-91

Sample No.: 36921

P.O. NO.: 44469

Sample Description: SITE 5 SANDBAR

Date Taken: 04-04-91

Date Received: 04-05-91

Parameters	Results	Units
PESTICIDES/PCB		
PCB-1016	<1.0	ug/g
PCB-1221	<1.0	ug/g
PCB-1232	<1.0	ug/g
PCB-1242	<1.0	ug/g
PCB-1248	<1.0	ug/g
PCB-1254	<1.0	ug/g
PCB-1260	<1.0	ug/g
Aldrin	<0.25	ug/g
Chlordane	<2.5	ug/g
Dieldrin	<0.25	ug/g
4,4'-DDD	<0.25	ug/g
4,4'-DDE	<0.25	ug/g
4,4'-DDT	<0.25	ug/g
Alpha-endosulfan	<0.25	ug/g
Beta-endosulfan	<0.25	ug/g
Endosulfan sulfate	<0.25	ug/g
Endrin	<0.25	ug/g
Endrin aldehyde	<0.25	ug/g
Heptachlor	<0.25	ug/g
Heptachlor epoxide	<0.25	ug/g
Alpha-BHC	<0.25	ug/g
Beta -BHC	<0.25	ug/g
Gamma - BHC (Lindane)	<0.25	ug/g
Delta - BHC	<0.25	ug/g
Methoxychlor	<0.25	ug/g
Toxaphene	<5.0	ug/g
SURROGATE RECOVERY	c	
Dibutylchlorendate	75.	%

Steve Johnson
Steve Johnson
Project Manager

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ANALYTICAL REPORT

Mr. John Larden
WEHRAN ENGINEERING
7205 Shadeland Station
Suite 120
Indianapolis, IN 46256

05-14-91

Sample No.: 36922

P.O. NO.: 44469

Page 7

Sample Description: SITE 7 WESTERN SHORE AT BIG MONON

Date Taken: 04-04-91

Date Received: 04-05-91

Parameters	Results	Units
COD	8900.	ug/g
Cyanide, Total	<0.25	ug/g
Nitrogen, Ammonia	5.3	ug/g
Oil & Grease, Soxhlet	14.	ug/g
Phenol	<0.125	ug/g
Solids, Total	75.	%
Arsenic, Total	10.	ug/g
Cadmium, Total	<0.50	ug/g
Chromium, Total	<2.0	ug/g
Lead, Total	<2.5	ug/g
Mercury, Total	<0.02	ug/g
Selenium, Total	<2.	ug/g
Silver, Total	<0.5	ug/g

Steve Johnson
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ANALYTICAL REPORT

Mr. John Larden
WEHRAN ENGINEERING
7205 Shadeland Station
Suite 120
Indianapolis, IN 46256

05-14-91

Sample No.: 36922

P.O. NO.: 44469

Sample Description: SITE 7 WESTERN SHORE AT BIG MONON

Date Taken: 04-04-91

Date Received: 04-05-91

Parameters	Results	Units
PESTICIDES/PCB		
PCB-1016	<1.0	ug/g
PCB-1221	<1.0	ug/g
PCB-1232	<1.0	ug/g
PCB-1242	<1.0	ug/g
PCB-1248	<1.0	ug/g
PCB-1254	<1.0	ug/g
PCB-1260	<1.0	ug/g
Aldrin	<0.25	ug/g
Chlordane	<2.5	ug/g
Dieldrin	<0.25	ug/g
4,4'-DDD	<0.25	ug/g
4,4'-DDE	<0.25	ug/g
4,4'-DDT	<0.25	ug/g
Alpha-endosulfan	<0.25	ug/g
Beta-endosulfan	<0.25	ug/g
Endosulfan sulfate	<0.25	ug/g
Endrin	<0.25	ug/g
Endrin aldehyde	<0.25	ug/g
Heptachlor	<0.25	ug/g
Heptachlor epoxide	<0.25	ug/g
Alpha-BHC	<0.25	ug/g
Beta -BHC	<0.25	ug/g
Gamma - BHC (Lindane)	<0.25	ug/g
Delta - BHC	<0.25	ug/g
Methoxychlor	<0.25	ug/g
Toxaphene	<5.0	ug/g
SURROGATE RECOVERY	c	
Dibutylchlorendate	74.	%

Steve Johnson

Steve Johnson
Project Manager

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ANALYTICAL REPORT

Mr. John Larden
WEHRAN ENGINEERING
7205 Shadeland Station
Suite 120
Indianapolis, IN 46256

05-14-91

Sample No.: 36923

P.O. NO.: 44469

Sample Description: SITE 9 NORTH SHORE AT POINT UPSTREAM

Date Taken: 04-04-91

Date Received: 04-05-91

Parameters	Results	Units
COD	51,000.	ug/g
Cyanide, Total	<0.25	ug/g
Nitrogen, Ammonia	42.	ug/g
Oil & Grease, Soxhlet	250.	ug/g
Phenol	0.459	ug/g
Solids, Total	43.	%
Arsenic, Total	16.	ug/g
Cadmium, Total	0.60	ug/g
Chromium, Total	3.5	ug/g
Lead, Total	4.5	ug/g
Mercury, Total	<0.02	ug/g
Selenium, Total	<2.	ug/g
Silver, Total	<0.5	ug/g

Steve Johnson

Steve Johnson
Project Manager

NATIONAL ENVIRONMENTAL TESTING, INC.

NET Midwest, Inc.
Indianapolis Division
6964 Hillsdale Court
Indianapolis, IN 46250
Tel: (317) 842-4261
Fax: (317) 842-4286

ANALYTICAL REPORT

Mr. John Larden
WEHRAN ENGINEERING
7205 Shadeland Station
Suite 120
Indianapolis, IN 46256

05-14-91

Sample No.: 36923

P.O. NO.: 44469

Sample Description: SITE 9 NORTH SHORE AT POINT UPSTREAM

Date Taken: 04-04-91

Date Received: 04-05-91

Parameters	Results	Units
PESTICIDES/PCB		
PCB-1016	<1.0	ug/g
PCB-1221	<1.0	ug/g
PCB-1232	<1.0	ug/g
PCB-1242	<1.0	ug/g
PCB-1248	<1.0	ug/g
PCB-1254	<1.0	ug/g
PCB-1260	<1.0	ug/g
Aldrin	<0.25	ug/g
Chlordane	<2.5	ug/g
Dieldrin	<0.25	ug/g
4,4'-DDD	<0.25	ug/g
4,4'-DDE	<0.25	ug/g
4,4'-DDT	<0.25	ug/g
Alpha-endosulfan	<0.25	ug/g
Beta-endosulfan	<0.25	ug/g
Endosulfan sulfate	<0.25	ug/g
Endrin	<0.25	ug/g
Endrin aldehyde	<0.25	ug/g
Heptachlor	<0.25	ug/g
Heptachlor epoxide	<0.25	ug/g
Alpha-BHC	<0.25	ug/g
Beta -BHC	<0.25	ug/g
Gamma - BHC (Lindane)	<0.25	ug/g
Delta - BHC	<0.25	ug/g
Methoxychlor	<0.25	ug/g
Toxaphene	<5.0	ug/g
SURROGATE RECOVERY	c	
Dibutylchlorendate	79.	%

Steve Johnson

Steve Johnson
Project Manager

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ANALYTICAL REPORT

Mr. John Larden
WEHRAN ENGINEERING
7205 Shadeland Station
Suite 120
Indianapolis, IN 46256

05-14-91

Sample No.: 36925

P.O. NO.: 44469

Sample Description: SITE 11 DOWNSTREAM OF UNNAMED DITCH

Date Taken: 04-04-91

Date Received: 04-05-91

Parameters	Results	Units
COD	35,000.	ug/g
Cyanide, Total	<0.25	ug/g
Nitrogen, Ammonia	33.	ug/g
Oil & Grease, Soxhlet	230.	ug/g
Phenol	0.786	ug/g
Solids, Total	70.	%
Arsenic, Total	16.	ug/g
Cadmium, Total	<0.50	ug/g
Chromium, Total	2.4	ug/g
Lead, Total	<2.5	ug/g
Mercury, Total	<0.02	ug/g
Selenium, Total	<2.	ug/g
Silver, Total	<0.5	ug/g

Steve Johnson

Steve Johnson
Project Manager

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ANALYTICAL REPORT

Mr. John Larden
WEHRAN ENGINEERING
7205 Shadeland Station
Suite 120
Indianapolis, IN 46256

05-14-91

Sample No.: 36925

P.O. NO.: 44469

Sample Description: SITE 11 DOWNSTREAM OF UNNAMED DITCH

Date Taken: 04-04-91

Date Received: 04-05-91

Parameters	Results	Units
PESTICIDES/PCB		
PCB-1016	<1.0	ug/g
PCB-1221	<1.0	ug/g
PCB-1232	<1.0	ug/g
PCB-1242	<1.0	ug/g
PCB-1248	<1.0	ug/g
PCB-1254	<1.0	ug/g
PCB-1260	<1.0	ug/g
Aldrin	<0.25	ug/g
Chlordane	<2.5	ug/g
Dieldrin	<0.25	ug/g
4,4'-DDD	<0.25	ug/g
4,4'-DDE	<0.25	ug/g
4,4'-DDT	<0.25	ug/g
Alpha-endosulfan	<0.25	ug/g
Beta-endosulfan	<0.25	ug/g
Endosulfan sulfate	<0.25	ug/g
Endrin	<0.25	ug/g
Endrin aldehyde	<0.25	ug/g
Heptachlor	<0.25	ug/g
Heptachlor epoxide	<0.25	ug/g
Alpha-BHC	<0.25	ug/g
Beta -BHC	<0.25	ug/g
Gamma - BHC (Lindane)	<0.25	ug/g
Delta - BHC	<0.25	ug/g
Methoxychlor	<0.25	ug/g
Toxaphene	<5.0	ug/g
SURROGATE RECOVERY	c	
Dibutylchlorendate	77.	%

Steve Johnson

Steve Johnson
Project Manager

NET®

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Indianapolis Division
6964 Hillsdale Court
Indianapolis, IN 46250
Tel: (317) 842-4261
Fax: (317) 842-4286

CHAIN OF CUSTODY

Client International Science & Technology	Project Name LAKE SHAFER
Send Report to: Mike Bonoff	
Address P.O. BOX 349 10501 HAGUE ROAD FISHERS, IN 46038	Collected by: J. MARKUSIC J. MARTIN
Telephone # 317/841-9880	

Collection Information								Parameters														
Sample ID	Sampling Location	Date	Time	GRAB	COMP	Sample Type	No. of Container	Total Metals	Cyanide	Phenols	Ammonia	Oil & Gas	COD	PCBs & pesticides	Total Solids	Solids by Weight	Sett. Solids	BOD				
Site 1	Lowe's Bridge	4/4/91	9:30A	X		Sediment	1															
~~Site 2~~	~~Mid-River @ Williams Ditch~~	~~4/4/91~~	~~9:47~~																			
Site 3	Western Sand Bar @ Timmons Ditch	4/4/91	10:08	X		Sediment	1															
Site 5	Sandbar	4/4/91	10:43	X		"	1															
Site 7	Western shore @ Big Monon Ditch	4/4/91	11:20	X		"	1															
Site 9	North Shore @ Point upstream of Big Monon D.	4/4/91	11:55	X		"	1															
Site 11	Downstream of unnamed Ditch on E. Shore	4/4/91	12:20	X		"	1															
*Site 12	Bridge @ Buffalo	4/4/91	12:35	X		"	1															

Remarks: * Analyze Site #12 only if one of the other samples is not usable

Relinquished by:	Date	Time	Received by:	Date	Time
Jim Martin	4/5	11:45			

Shipping Notes/Lab Comments	Received for NET Midwest by:		
	Faith Thomas	4-5-91	11:45

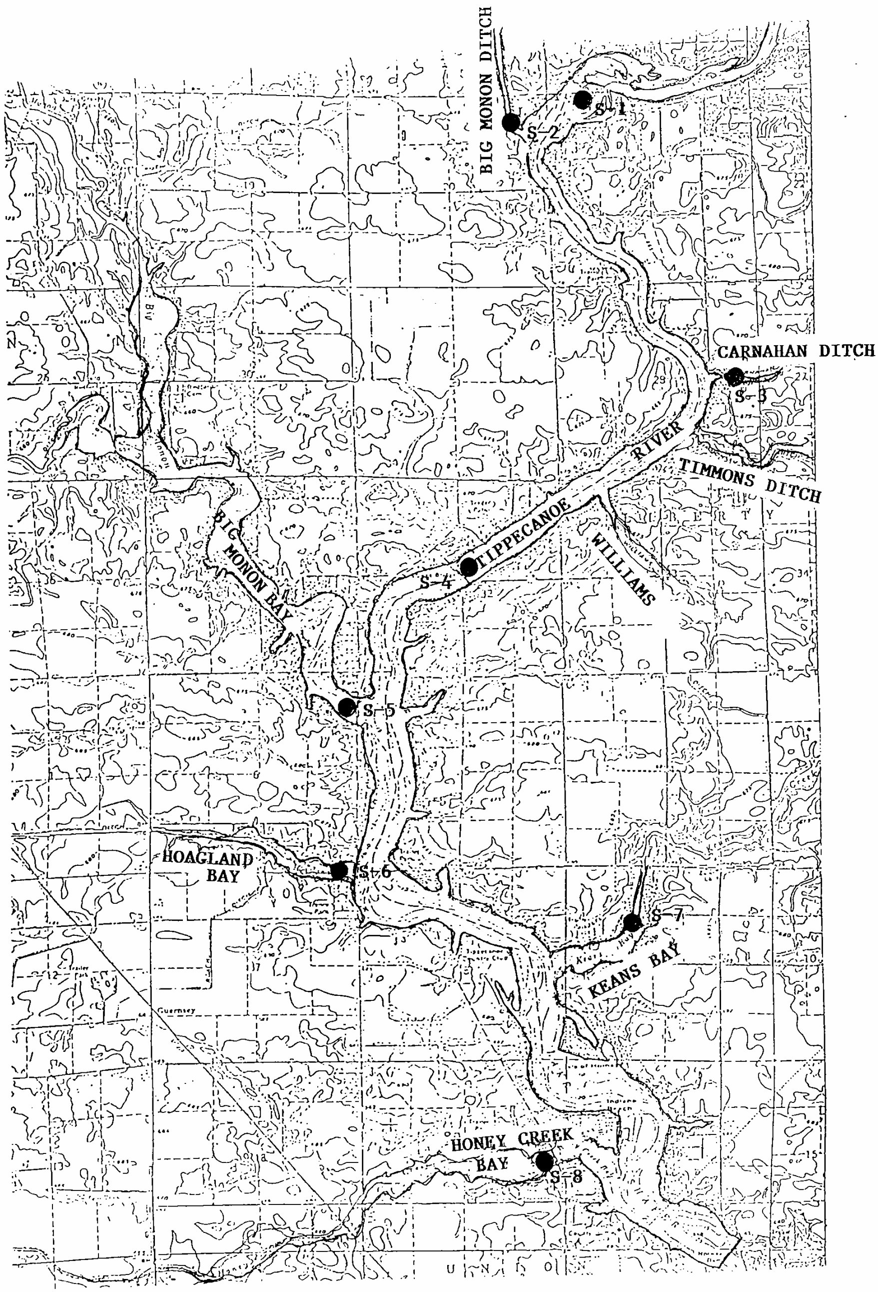
Samples Field Filtered: ___ Yes ___ No

Seals Intact Upon Receipt: ___ Yes ___ No ___ N/A

APPENDIX I

SUSPENDED SEDIMENT SAMPLING LOCATION MAP AND ANALYTICAL RESULTS

SUSPENDED SEDIMENT SAMPLING LOCATIONS (DECEMBER 7, 1994)



LAKE SHAFER AND TRIBUTARIES (MONTICELLO NORTH QUADRANGLE)

Environmental Laboratory Services

250 West 84th Drive • Merrillville, IN 46410 • Tel: 219-769-8378 • Fax: 219-769-1664

WET CHEMISTRY
ANALYTICAL RESULTS

Client: K & S Testing and Engineering Inc.

Analyte: TSS
Analyte Method: 160.2
Sample Matix: Aqueous
Date Sampled: 12/07/94
Date Received: 12/15/94
Date Analyzed: 12/20/94
Analyst: KDS
Client Project ID: 2465
Lab Number(s): 949646 - 949653

SAMPLE IDENTIFICATION	CONCENTRATION (mg/L)	QUANTITATION LIMIT (mg/L)
S - 1, Tippecanoe River	69.0	10.0
S - 2, Big Monon Ditch	436	10.0
S - 3, Carnahan Ditch	31.0	10.0
S - 4, Lake Shafer (Near Long's Bridge)	21.0	10.0
S - 5, Big Monon Bay	19.0	10.0
S - 6, Hoagland Bay	256	10.0
S - 7, Keans Bay	30.0	10.0
S - 8, Honey Creek Bay	184	10.0

Respectfully Submitted,
A2I

K & S Testing and Engineering Inc.

9715 Kennedy Ave. Highland, Indiana Phone: (219) 924-5231

CHAIN OF CUSTODY RECORD

PROJ. NO.: 2465

PROJECT NAME: Lake Shafer Feasibility Study Monticello, IN.

SAMPLERS: (Signature) Bob Coates

STA. NO.	DATE	TIME	COMP.	GRAB	STATION LOCATION	NO. OF CONTAINERS	Total Suspended Solids						REMARKS
S-1	12/7/94				TIPPECANOE RIVER (WATER)	1	✓						Please Return Signed Coc. Form 949646
S-2	12/7/94				BIG MONON DITCH (WATER)	1	✓						949647
S-3	12/7/94				CARNAHAN DITCH (WATER)	1	✓						949648
S-4	12/7/94				LAKE SHAFER (NEAR COMB'S BRIDGE) WATER	1	✓						949649
S-5	12/7/94				BIG MONON BAY (WATER)	1	✓						949650
S-6	12/7/94				HOAGLAND BAY (WATER)	1	✓						949651
S-7	12/7/94				KEANS BAY (WATER)	1	✓						949652
S-8	12/7/94				HONEY CREEK BAY (WATER)	1	✓						949653

Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)
Bob Coates	12/15/94				
Relinquished by: (Signature)	Date / Time	Received by: (Signature)	Relinquished by: (Signature)	Date / Time	Received by: (Signature)

Relinquished by: (Signature)	Date / Time	Received for Laboratory by: (Signature)	Date / Time	Remarks
		Phil Kanclowicz	12/15/94 12:10	

Distribution: Original Accompanies Shipment; Copy to Coordinator Field Files

APPENDIX J

TRAP EFFICIENCY CURVES

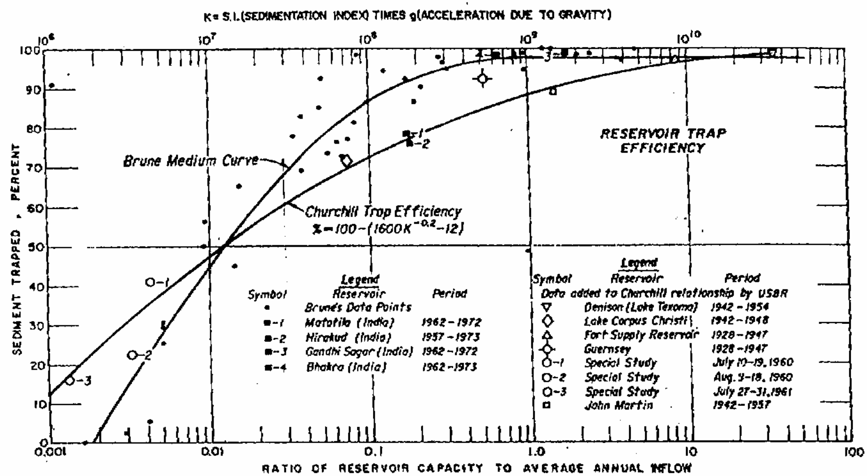


Figure A-9.—Trap efficiency curves. From Brune [22] and Churchill [23]. 103-D-1810.